New Series
Article Section

Vol. XVI. No. 5
September, 1909

THE

Psychological Review

EDITED BY
J. MARK BALDWIN

HOWARD C. WARREN
PRINCETON UNIVERSITY

AND

JOHN B. WATSON
JOHNS HOPKINS UNIVERSITY

JAMES R. ANGELL, CHICAGO UNIVERSITY (*Editor Psychological Monographs*).

WITH THE CO-OPERATION FOR THIS SECTION OF

A. C. ARMSTRONG, WESLEYAN UNIVERSITY; C. M. BAKEWELL, YALE UNIVERSITY; ALFRED BINET, ÉCOLE DES HAUTES-ÉTUDES, PARIS; W. L. BRYAN, INDIANA UNIVERSITY; WILLIAM CALDWELL, MCGILL UNIVERSITY; MARY W. CALKINS, WELLESLEY COLLEGE; JOHN DEWEY, COLUMBIA UNIVERSITY; C. LADD FRANKLIN, BALTIMORE; H. N. GARDINER, SMITH COLLEGE; G. M. STRATTON, UNIVERSITY OF CALIFORNIA; P. JANET, COLLÈGE DE FRANCE; JOSEPH JASTROW, UNIVERSITY OF WISCONSIN; C. H. JUDD, CHICAGO UNIVERSITY; ADOLF MEYER, JOHNS HOPKINS UNIVERSITY; C. LLOYD MORGAN, UNIVERSITY COLLEGE, BRISTOL; HUGO MÜNSTERBERG, HARVARD UNIVERSITY; E. A. PACE, CATHOLIC UNIVERSITY, WASHINGTON; R. M. WENLEY, UNIVERSITY OF MICHIGAN.

CONTENTS.

Time-relations of the Affective Processes. TAIZO NAKASHIMA, 303.

A Note on the Accuracy of Discrimination of Weights and Lengths. E. L. THORNDIKE, 340.

A Range of Information Test. G. M. WHIPPLE, 347.

Resistance of Keys as a Factor in Reaction Times. J. V. BREITWIESER, 352.

THE REVIEW PUBLISHING CO.,
41 NORTH QUEEN ST., LANCASTER, PA.
AND BALTIMORE, MD.

AGENTS: G. E. STECHERT & CO., LONDON (2 Star Yard, Carey St., W. C.); LEIPZIG (Hospital St., 10); PARIS (76 rue de Rennes); MADRID, D. JORRO (Calle de la Paz, 23).

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Annual Subscription to Both Sections, $4.50, Canada $4.65 (Postal Union, $4.80); Bulletin Alone, $2.50, Canada, $2.60 (Postal Union, $2.70); Current Numbers of The Review, 50c.; of Bulletin, 25c. (special issues 50c.).

THE PSYCHOLOGICAL INDEX

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PUBLISHED BY

THE REVIEW PUBLISHING CO.,

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N. S. Vol. XVI. No. 5. September, 1909.

THE PSYCHOLOGICAL REVIEW.

TIME-RELATIONS OF THE AFFECTIVE PROCESSES.[1]

BY TAIZO NAKASHIMA, PH.D.

I. STUDY BY THE DIRECT REACTION METHOD.

Experiments with Color Combinations.

The problem of the present investigation was twofold, — first, the determination of the time necessary for the arousal of an affection; and secondly, that of the dependence of affective intensity upon the duration of stimulus. The apparatus used was Hering's modification of Ludwig's kymograph. A long roll of paper, on which thirty-two color combinations were pasted, was stretched around the drum and the cylinder. The observer sat at a distance of about 1 m. from the screen, which stood close to the drum, and had an oblong window (3 × 5 cm.). Two colored papers combined horizontally served as stimulus, and the line of junction was so adjusted that it came just on the middle line of the window. Thus the vertical length of each colored paper actually seen by the observer was 2.5 cm. The horizontal length of each color combination was 4 cm., and the distance between one color combination and another was also 4 cm. The length of the roll of paper was 256 cm. By dividing the time necessary for a complete revolution of the paper by this total length, we obtain the amount of time necessary to pass through 1 cm. The rapidity of the drum was graded in 7 degrees above and below 0 at the center. The exposure-distance of each stimulus was thus 7 cm. (complete and partial exposure), and

[1] The experimental work in Section I. was done in the Harvard laboratory during 1906–7; that in Sections II. and III. was done in the Cornell laboratory during 1908–9.

the interval between the stimuli, *i. e.*, the length of the background was 1 cm. With speed 0, the time necessary for a complete revolution of the drum was 3′ 50″; therefore, the time of exposure of stimulus was 6.3″. With the other six speeds, the times in seconds are as follows:

Speed.	Time of Complete Revolution.	Time of Exposure.
1	110	3.01
2	75	2.03
3	55	1.47
4	45	1.26
5	35	0.98
6	30	0.84

The 32 (Milton-Bradley) color combinations selected were as follows: I., BV and GS1 (green shade no. 1); II., YOS1 and VT1 (violet tint no. 1); III., VRS2 and RS2; IV., GT1 and VRT2; V., Y and BV; VI., ROT1 and VRT1; VII., ROS1 and VRS2; VIII., RS1 and VRS2; IX., Y and VR; X., O and VT2; XI., RS2 and Black; XII., B and OYS2; XIII., V and YG; XIV., Warm Gray No. 2 and A-Red, Dark; XV., GY and BV; XVI., ORT2 and A-Red Violet, Light; XVII., VRT2 and Neutral Gray 1; XVIII., VRS2 and BVS2; XIX., YG and ORT2; XX., GBS2 and A-Red, Dark; XXI., V and GS1; XXII., OS2 and RVS2; XXIII., GY and VT2; XXIV., YG and VT2; XXV., BV and YG; XXVI., VS2 and RS2; XXVII., VRT2 and A-Green, Light; XXVIII., BVS2 and RS1; XXIX., Warm Gray 2 and RVS2; XXX., VRS2 and GS2; XXXI., OR and G; XXXII., Y and BS2.

Every judgment on the first stimulus of a series was stricken out, since the speed of the drum was at first slow; and that reaction was supplemented by one taken later, with normal and uniform speed. The first color of a series was 1, 32 or 15. The change of the speed-pointer above or below zero, caused the drum to reverse its direction, and this gave the opportunity of arranging series in ascending and descending order. Usually, one complete series was made in two experimental hours, to avoid too frequent repetition of the same stimuli. The observers were instructed to pass affective judgments upon the color impressions in terms of P–U, and in the seven steps: 1 very pleasant; 2 moderately pleasant; 3 just pleasant; 4 indiffer-

ent; 5 just unpleasant; 6 moderately unpleasant; 7 very unpleasant. The judgment in these steps was to be passed on the basis of the affection aroused during the exposure of the stimulus, and it was to be registered as '4' when there was no pleasantness or unpleasantness during the time of exposure. The actual procedure of the experiment was as follows. About 3 sec. after 'Ready,' and at the signal 'Now,' the experimenter started the drum, and the observer gave his judgment, '2,' '5' or '4,' for instance, which a third person registered on the prearranged laboratory tablet. After the thirty-second judgment, the experimenter stopped the drum and received from the observer any remarks on the experiences that suggested themselves. Then the recorder took the place of the observer, and the previous observer kept the record. The experiments were made during the months of October, November, and December, 1906. They were performed in ordinary diffuse daylight; every care was taken to keep the light as constant as possible, by the adjustment of curtains at the windows of the room, The observers were Professor E. B. Holt (*H*), Miss E. L. Davis (*D*), Messrs. C. A. Barnes (*B*), C. S. Berry (*Br*), E. P. Frost (*F*), A. Mitchell (*M*), C. A. Pierce (*P*), H. Reverdin (*R*), H. M. Sheffer (*S*), H. Taylor (*T*), K. T. Waugh (*W*).[1] The results of eight observers only are given here, since the other three could not complete the series. The following tables show the results which were obtained after three complete series (672 reactions) of preliminary experiments with each observer, made for the purpose of learning and standardizing the scale of arbitrary affective values. All invalid series have been eliminated. Immediately before the preliminary series, a view of the whole set of stimuli was given to the observer for some time, to furnish him with a rough estimation of the relative affective position of each stimulus in the series.

In these tables, the figures in the first horizontal row indicate the seven times of exposure 0 to 6; the figures in the first vertical row show the number of affective judgments of the same grade between the limits 1 and 7. In Table I. the figures

[1] All except *H* and *T* were graduate students and members of the laboratory.

TABLE I.

OBSERVER H.

	0	1	2	3	4	5	6
5	1.0	1.6	1.4	1.6	1.6	1.8	1.9
7	2.0	2.7	2.5	2.7	2.8	3.0	2.9
14	3.0	3.7	3.5	3.8	3.8	4.1	4.0
12	4.0	4.2	4.0	4.1	4.0	4.0	4.0
14	5.0	4.7	4.6	3.9	4.0	4.2	4.0
9	6.0	4.8	4.7	5.0	4.3	4.3	4.4
3	7.0	5.7	6.0	4.7	4.0	4.4	4.4
	12	15	16	19	26	30	34

TABLE II.

OBSERVER BR.

	0	1	2	3	4	5	6
13	1.0	0.3	0.2	0.4	0.3	0.4	0.5
7	2.0	0.3	0.1	1.0	0.9	1.0	1.7
7	3.0	0.6	0.9	0.8	0.8	1.0	1.0
2	4.0	0	0	0	0	0	0
15	5.0	—.4	—.6	—.4	—.6	— .8	— .8
14	6.0	—.2	—.7	—.8	—.8	—1.0	—1.0
6	7.0	—.2	—.6	—.5	—.9	—1.0	—1.0
	2	4	5	6	6	8	10

TABLE III.

OBSERVER D.

	0	1	2	3	4	5	6
	—	—	—	—	—	—	—
9	2.0	0.5	0.4	0.4	0.4	0.4	0.5
14	3.0	0.5	0.4	0.3	0.4	0.4	0.5
27	4.0	—.1	0.1	0	0	0	0
14	5.0	—.6	—.4	—.4	—.8	—.8	1.0
	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
	27	27	27	28	32	33	37

TABLE IV.

OBSERVER F.

	0	1	2	3	4	5	6
2	1.0	0	0	0	0	0	0
6	2.0	0.3	0.3	0.4	0.4	0.6	0.5
11	3.0	0.3	0.2	0.3	0.4	0.6	0.8
11	4.0	—.2	—.2	—.1	—.1	0	0
8	5.0	0	0	—.2	—.2	—.4	—.4
12	6.0	—.1	—.4	—.4	—.3	—.4	—.5
14	7.0	—.1	—.1	—.2	—.2	—.4	—.8
	11	8	11	11	12	13	16

TABLE V.

OBSERVER M.

	0	1	2	3	4	5	6
4	1.0	0	0	0	0	0	0
1	2.0	3	3	3	3	4	4
12	3.0	0.4	1.0	1.1	0.9	0.8	0.8
5	4.0	0.2	0.1	0.2	0.2	0	0
17	5.0	—.2	0	—.2	—.3	—.4	— .6
16	6.0	—.1	—.2	—.2	—.5	—.4	—1.2
9	7.0	—.4	—.5	—.8	—.9	—.9	—1.2
	5	12	13	13	14	18	33

TABLE VI.

OBSERVER S.

	0	1	2	3	4	5	6
13	1.0	0.3	0.2	0.2	0.4	0.4	0.6
4	2.0	0.5	0.3	0.3	0.3	1.3	1.5
11	3.0	0.7	0.5	0.5	0.6	0.5	0.6
6	4.0	—.2	—.2	— .1	— .1	0	0
10	5.0	—.7	—.8	—1.2	— .8	— .7	— .8
9	6.0	—.6	—.5	— .4	—1.0	—1.0	—1.4
11	7.0	—.5	—.4	— .4	— .8	— .9	—1.7
	6	10	6	8	12	17	20

TABLE VII.

OBSERVER W.

	0	1	2	3	4	5	6
11	1.0	0 .4	0.3	0.3	0.3	0.3	0.4
20	2.0	0 .7	0.6	1.0	0.9	1.2	1.2
16	3.0	0 .1	0	0	0.4	0.6	0.8
8	4.0	— .1	0	0.1	0	0	0
6	5.0	— .9	— .8	— .8	—1.0	0.5	0.8
3	6.0	—1.0	—1.1	—1.3	—1.0	—1.9	—2.0
	—	—	—	—	—	—	—
	8	8	10	12	13	15	18

TABLE VIII.

OBSERVER T.

	0	1	2	3	4	5	6
	—	—	—	—	—	—	—
10	2.0	0.1	0.2	0.3	0.3	0.4	0.5
25	3.0	0	0	0.1	0.1	0.3	0.6
11	4.0	0.1	0	—.1	0	0	0
18	5.0	—.1	—.2	—.2	—.3	—.3	—.5
	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
	11	11	12	12	13	16	18

under the exposure times are averages, obtained by the following mode of calculation. (1) Count up the number of times a given affective judgment (1, 2, 3, . . . 7) occurs under heading 0. (2) Sum up the judged values for the same stimuli under the other time-headings 1 to 6. Divide by the number of occurrences found in (1). If judgment 3, for instance, occurs 5 times under 0 (for stimuli 1, 7, 10, 13, 20), then sum up the judged-values for these same stimuli (1, 7, 10, 13, 20) under each time-heading 1–6, and divide by 5. — In the remaining 7 tables, the figures under the grades 1–8 are the differences between the standard values under the 0 exposure, and the values under those other grades which were obtained in the mode explained above. The figures in the last horizontal row of each table indicate the number of the stimulus judged '4' under the respective grades of exposure, out of the two complete series, 448 judgments, which are the total data of the 'averages of the judgments.' The tables show clearly that *affective intensity decreases with decrease of time of exposure*. There are, however, disturbing factors. In Table I. the figures 4.2 and 4.1 in judgment 4 are certainly the effect of such factors. These deviations from the 4 show that the indifferent stimuli at the 0 exposure are occasionally judged for other steps. Affective variations due to unknown disturbing factors are noticed in other steps and in all other tables. In Table III. the figures — .1 and 0.1 in judgment 4 indicate that there are judgments passed which deviate from the 4 towards opposite directions. With *F* and *M* the variations in judgment 4 are slightly greater than those in the case of *D*, and the tendency of variation is decidedly in one direction. *S* shows a stronger tendency of deviation from the 5 than from the 3. With *Br*, *T* and *W* the deviations from the 4 are very slight. All these and similar variations we admit. But they are very slight as compared with the general effect of the time of exposure, as can be seen from examination of the original records. In all the tables, the increase of the number of the judgment 4, and the convergence towards the 4 of all other grades of judgment with decrease of the time of exposure, are definite beyond doubt.

M and *S* had at first much difficulty in passing an affective

judgment in the seven steps under our experimental conditions, although later the difficulty disappeared, except during the exposures 5 and 6. Other observers also had more or less difficulty, but soon learned to adapt themselves to the required conditions. *M* and *S* said that, with the exposures 5 and 6, the shortness of exposure and the need of quick judgment seemed to oblige them to pass judgment from memory; and in so far the judgment was intellectual. *Br* and *F* had no such difficulty, but also thought that their judgments might be purely intellectual. The experimenter then explained the nature of affective habituation, and asked them strictly to observe the rules laid down for judgment, and to say '4' whenever they found no affection during the exposure. The results were much the same as before, and no observer could be positively sure that his judgments were purely intellectual. *D*, *T* and *W* seem to have had more or less difficulty, but did not express themselves definitely on the question. *H* remarked that a few stimuli might possibly have been dropped without being included in the affective judgments; *i. e.*, might have been passed as '4,' while they had in reality some affective tone. All observers were unanimous in their experience of definite affections during exposure time 4. We may, then, take the times of exposures 5 and 6 as dubious, and conclude that *the shortest time necessary for an affection to arise varies from 0.84 to 0.98 sec.*

Experiments with Geometrical Figures.

The stimuli used in this experiment were such geometrical figures as stars, triangles, dots, circles, crosses, Japanese chrysanthemum patterns, oblique and straight lines, angles, etc. From three to five such figures were drawn in certain spatial relations within a rectangular frame (2 × 7.5 cm.) of black lines. The whole figure with the frame was pasted on another larger rectangular piece (4 × 10 cm.) of white paper. The distance between one piece and another was 4 cm., while the distance between one frame and another was 6 cm. Thirty-two such pieces were pasted on a roll of paper like that used in the preceding experiment. The window in the screen was 4 × 10 cm.; the horizontal distance of exposure of each stimulus was,

therefore, 6 cm. (complete and partial exposure), and the interval, *i. e.*, the distance of the background between two frames, was 2 cm. One complete series consisted as before of 224 reactions. The observers were instructed to give their judgments, if possible, on the total affection aroused by the figure with its frame. All other requirements and experimental conditions were exactly the same as in the experiment with color combinations. *H*, *D*, *B*, *Br*, *F*, *M*, *R*, *S*, *T* and *W* again served as observers. The work was done during the months of January, February, and March, 1907. The results to be stated below were obtained on the basis of two complete series, after two complete series of preliminary experiments.

The general result of the present experiment is practically the same as that of the preceding. In this experiment, however, the influence of disturbing factors is much less, while that of the decrease of exposure time is considerably greater, as is shown both by the original records and by their statistical examination as in the last experiment. All the observers, except *M* and *S*, found that during exposure 6 most of the stimuli aroused no affection, and a few remaining stimuli had hardly time enough to develop an affective reaction during the exposure. *M* and *S* observed that during exposure 6 there was absolutely no affection, and that the judgments with the next exposure might be purely intellectual; only at the end of exposure 4 there were a few stimuli which aroused an affective tone. We may, then, conclude that *the shortest time necessary for the affection to arise varies from 0.72 to 1.08 sec.*

We are now to discuss the method and the results obtained by the method. One might question whether the times determined in the above two experiments do not include the time for judgment. But that is not necessarily the case; for the observers were instructed carefully to note the relation of the time-limit of exposure to the moment of appearance of the affection, not its relation to the completion of their judgment, and to record on the basis of that observation only. The time obtained may, however, be somewhat longer than it would have been if we had asked for a record of the first bare experience of affection. On the other hand, if we had required this simplest form

of reaction, the response would have been impulsive only, and the result must have been quite dubious. At any rate, all our observers were certain that there was no single case in which affection appeared simultaneously with, or earlier than, the sensation; it always appeared distinctly later than the cognition of the impression.

In the ordinary chronometric reaction, what is registered is a certain conscious moment and the time of the physical movement of response. Consequently, the rapidity of the reaction movement, and every influence on that rapidity, cause a difference in the time measured. The time determined by this method never corresponds to a real mental time. It is a time known through the intermediation of a certain movement; a time of indirect reaction. In our reaction, the time registered is a certain conscious moment, which we seek to determine, and the observer's task is to note the time-relation of the stimulus to this conscious point; while the expression of his observation or reaction might be quicker or slower, without any consequence for the determination of the time. Thus the reaction by our method is direct, and the time found represents an actual mental point in its relation to the objective time of stimulation. The present direct reaction method, therefore, avoids the whole problem of the physiological time of the reaction movement, and eliminates the possible error that arises from the variation of that movement. Further, the method saves the time and toil necessary for the graphic and chronoscopic reaction methods, since it needs no objective device for registering reaction-times. It should also be remarked that the new method has no essential connection with the serial presentation of stimuli, and with passing judgment in seven steps, although we combined these procedures with the method in the present study. We resorted to serial presentation, because it seemed desirable to prevent the possible persistence of the affective process, aroused by a stimulus, by the inhibition through a following stimulus, so that there could not be any confusion of an actual affection with the affection attaching to the memorial after-image of a precedent stimulus. The scheme proved efficient, as was reported by the observers. Moreover, the need of quick successive judgments

gave the least chance for disturbing association and reflection, and required uniform concentration of attention.

The passing of judgment in seven steps is purely accidental to the method; it was required simply because we sought to determine the relation of affective intensity to time of exposure. The main issue as concerns the method is that the direct reaction method is feasible and reliable, and has important advantages, even when it is applied to the affective processes pleasantness and unpleasantness.

Experiments with Complex Visual Impressions.

The experience of the preceding experiments encouraged us to attempt a further study of the time-relations of affective process with the same direct reaction method. In this experiment, however, a single stimulus was presented, instead of the serial presentation of a number of stimuli. The apparatus consisted of two parts: the one was Meumann's time-sense apparatus, and the other was an exposure box, 32 cm. by 21 cm. by 18 cm. This was painted black. The front of the box was open, as far down as 14.5 cm. from the top. The lower part of the left side of the box, as far up as 16 cm. from the bottom, was covered by a door which was shut during the experiment, but could be opened for the introduction and removal of the stimulus. Two screens, just large enough to cover the front, were held up to the top of the box, at equal distances from each other, by two pairs of electromagnets; a third was held by a support. The screen was made of a light black wooden frame and a black cardboard inserted in the frame. On the second or middle screen, a stimulus was fastened, and the third or last screen with a check stimulus formed the background. The first pair of electromagnets, which held up the front screen, were connected by wires to the first contact on the scaled disc of the time-sense apparatus, and with a pole changer formed the first circuit. The second pair of electromagnets, which held up the middle screen, were connected to the second contact on the disc, and with wires and another pole changer formed the second circuit. When the contact at the first key was broken by one of the revolving arms, the front screen fell, and at the same time

the stimulus on the second screen appeared. The second screen fell, after a certain interval of time, when the second contact was broken by the other revolving arm. The observers were requested to record their observations after the screen had fallen, and, after a glance at the stimulus on the third screen, to check or destroy the affective process possibly remaining as an after-effect of the stimulus. The time for adjustment to the stimulus, before its appearance, was about 7 seconds, the commencement of the whirring noise of the wheel-work serving as the signal for attention. However, the actual duration of attention was, according to the report of the observers, about 4 seconds. The initial 7 seconds was found necessary for the introduction of uniformity in the rate of the revolving arms. The distance between the exposure box and the observer was 70–80 cm. The time of exposure, *i. e.*, the time between the fall of the first screen and that of the second, could be varied widely by fine steps, and exactly determined by measuring the distance passed by the arm between the first and the second break. The experiments were made during the months of March, April and May, 1907. They were performed in a completely dark room, except that an electric light of 5 c.p. at the front of the upper board of the box illuminated the stimulus. The same nine persons and the writer served as observers. The stimuli used were forty illustrative photographic pictures on postal cards (Detroit Photographic Co.), five Japanese postal cards, and ten plates of surgical diseases of the chest. The stimuli on the third screen were illustrative postal cards similar in their nature to those used as stimuli on the second screen. They were changed in every other experiment, keeping a constant relation to the stimuli on the middle screen. The observers were called upon to pay special attention to (1) the time-relation between the moment of the appearance of affection and the exposure of the stimulus, *i. e.*, whether it was aroused during or after the exposure; (2) the quality, intensity, vividness and duration of the affection; (3) the relation of the affection to the background, with especial reference to inhibition, reinforcement, and coexistence, if there were such processes; (4) associations, bodily reactions, etc. They were also told that the quality and intensity might be

recorded in the seven steps. Above all, they were carefully to observe the time-relations of the affective processes.

In the actual experimental procedure, if there were two cases in which no affection arose with one and the same exposure time, a further experiment was tried with the next longer exposure time; and if P or U was aroused, then the experiment was stopped, and the time was taken with another stimulus. If an exposure time was found in which an affection was aroused in the first or second experiment, the next shorter exposure was tried, until a time was found in which there occurred two cases of 'no affection.' The final time for 4 was determined by the same procedure as that for P–U, but after it was found we went on further to find the final time for P–U. Usually, in the next exposure grade P–U was aroused, and 2 trials were the average for all observers except *T* and *N* (4 trials). In other cases, 7 trials were the average for determining the final time of P–U or 4, except again for *T* and *N* (10 trials). There were only a few cases in which P–U after 4 did not arise even in an exposure time of 141.5 sec. In such cases, the trial was stopped, and the original time was taken as final for 4. The grade, *i. e.*, the interval between one exposure and the next, was .05 sec. In calculation of the times, therefore, .025 sec. was subtracted from the time in which an affection or a feeling was aroused, on the assumption that it must have been aroused between the exposure time in which there occurred two cases of no affection, and the time in which an affection was aroused. The following Table IX. shows the results of the time measurements.

TABLE IX.

Observer.	Direct Reaction Times of P-U.						Times of 'Indifferent.'					
	Range.	Median.	MV.	Av.	MV.	No.	Range.	Median.	MV.	Av.	MV.	No.
Barnes	31.5– 86.5	41.5	5.9	47.0	6.9	112	26.5–126.5	36.5	5.3	39.0	6.9	140
Berry	31.5– 66.5	39.0	6.0	39.0	6.0	172	31.5– 91.5	41.5	6.2	40.0	6.0	39
Davis	31.5–111.5	39.0	5.8	41.5	5.9	162	26.5–136.5	41.5	6.4	41.5	6.4	41
Frost	31.5–111.5	40.0	5.4	41.2	5.9	172	31.5– 96.5	42.0	6.0	42.6	5.9	36
Holt	36.5–141.5	49.0	6.9	51.5	6.9	183	41.5– 66.5	50.0	7.1	49.0	6.9	20
Mitchell	31.5–126.5	42.5	5.4	42.0	5.7	179	41.5–141.5	52.0	7.1	47.0	6.4	49
Nakashima	36.5– 86.5	40.5	5.4	41.5	5.6	346	31.5– 86.5	36.5	5.0	37.5	5.6	24
Sheffer	31.5–131.5	42.5	5.6	46.0	5.4	174	31.5–126.5	41.0	5.3	43.6	5.5	52
Taylor	31.5–111.5	39.0	6.0	40.0	7.0	225	31.5– 96.5	39.0	5.9	41.5	6.2	126
Waugh	36.5–141.5	48.5	6.8	50.0	6.9	178	41.5– 91.5	48.0	7.2	50.0	6.9	28

The figures under 'Number' indicate the total number of experiments. The stimuli were 55 in all, but the necessity of finishing the experiment within the academic year obliged us to reduce the number of the stimuli, and experiments on 30 stimuli only out of 55 were completed, these 30 including the stimuli that required the longest and the shortest times. The 25 stimuli eliminated were those which required intermediate times. The number with observer *T* is exceptionally large, because many extra hours were obtained from this observer in advance of the others, when the experimenter had not the adequate experience for reducing the number of the experiments. The experience obtained from the work with *T* and the writer's own observations enabled the experimenter to guess that such and such stimuli would require about such and such times; and thus he could try from the beginning the approximate exposure time in which an affection would be aroused. This is the reason why the numbers for the other observers are smaller. In the table, the 'indifferent' (4) means 'indifferent in regard to pleasantness or unpleasantness.' Thus it covers such things as the feelings of strain, excitement, curiosity, interest, surprise or shudder, wonder (strangeness), familiarity, recognition, a certain indescribable feeling, etc.[1] The observers used the word feeling in the ordinary way, and the 'indifferent feeling' is by no means a pure elementary affection. It is noteworthy, however, that the times of these indifferent feelings are practically the same as those of P–U, and in the case of *B* and *D* are even shorter than the latter. The times of both P–U and the indifferent feelings are also remarkably uniform. This is partly due to the fact that .05 sec. was taken as the unit of the grades, so that possible finer differences could not be brought out. However, even if we take the interval of the grades into account, the individual ranges and the ranges among the different observers are much smaller than might have been expected; for the possible maximum interval according to our mode of calculation is only .025 sec. More-

[1] These feelings are really Orth and Marbe's 'Bewusstseinslagen,' Ach's 'Wissen' or 'Bewusstheiten,' James' 'fringe of consciousness,' and as such may be a part of the consciousness of understanding; otherwise, they are nothing but organic sensations. Whether in the first case they are sensorial or non-sensorial is still a matter of dispute.

over, it should be remarked (1) that in the calculation of the times, no single time value was eliminated (except the extremely isolated times mentioned below), and that even in the simple reaction a range from the shortest time to its 2 or 2.5 times is not exceptional; (2) that the reactions were performed in the condition of ordinary naïve experience, without trying to eliminate anything which might be regarded as a disturbing factor from the standpoint of psychophysics; (3) that the greater variations are only exceptional cases; reference to the ranges in the table shows that the times 126.5, 131.5, and 141.5 were found only once with *B*, *D*, *H*, *S* and *W*; and finally (4) that the ranges in the table were obtained from a large variety of complex stimuli.

It seems, then, to follow from these considerations that the mode of variation of affective reaction-times is of the same order as that of sensory reaction-times. Even the absolute values of the averages and the medians in the table are practically the same as those of cognitive reactions, which are already known from reaction experiments on visual impressions made by various investigators. All the observers agreed that, although feeling appeared only after a more or less clear perception of the stimulus, the temporal disjunction was in most cases very slight. The introspective records of the observers are quite homogeneous, except for *H*, so that they may be presented later in a summary way. The following are *H*'s records taken from each last one of 55 stimuli:

Stimulus 1. Feeling of recognition and it was perhaps pleasant no. 3. But I cannot be sure that there was more than one quality.

Stimulus 2. Some mild feeling which I cannot describe.

Stimulus 3. Feeling no. '5,' slightly disagreeable owing to *color* (simply). Inhibited by background. No association. Feeling of dejection.

Stimulus 4. Clear perception, but no feeling. There was feeling from memory image.

Stimulus 5. No feeling during exposure. Feeling no. 2 *now* as I recall the picture. Perception clear during exposure.

Stimulus 6. Feeling no. 1 (*very* faint) inhibited at once by background. Association with Japanese art.

Stimulus 7. Clear perception, feeling no. 3, mildly restful.

Stimulus 8. Clear perception but no feeling during exposure. After exposure had feeling no. 5.

Stimulus 9. No pleasantness or unpleasantness. Surprise, and, I should think, horripilation to a slight degree, during exposure.

Stimulus 10. No feeling during exposure. But first picture and background together were no. 7, and gave me a sort of shudder.

Stimulus 11. Feeling no. 3, coming long after exposure, attached to memory of stimulus.

Stimulus 12. Clear percept but no feeling during exposure. Feeling no. 5 afterward. No relation between picture's feeling and background.

Stimulus 13. Feeling no. 6 at time of exposure. Fairly intense: one of irritating nervousness. Inhibited by background. No association. Bodily feeling of (my) withdrawal from stimulus.

Stimulus 14. Feeling no. 1 aroused faintly during exposure; became stronger after exposure and inhibited background for all but its (the background's) first moment of exposure.

Stimulus 15. Simply not time for a feeling although a pretty clear perception of stimulus.

Stimulus 16. No feeling during exposure. Memory image inhibited by background. Two or 3 sec. later feeling no. 5 attaching to original picture's memory image.

Stimulus 17. No feeling. If (as here) background is agreeable it has a strong tendency to inhibit picture and feeling-tone altogether.

Stimulus 18. Feeling no. 2 very faint. Inhibited by agreeable background.

Stimulus 19. Feeling no. 6, during exposure. Feeling of 'mussiness' perhaps of 'tension.'

Stimulus 20. Feeling no. 3 rather strong; inhibited by background.

Stimulus 21. No feeling during exposure. Background seemed to come as a feeling-tone, no. 6, was surging up. This inhibited background for a moment (after it had an instant appeared).

Stimulus 22. Mild intensity of feeling no. 1, coming after I had seen background and looked away from it.

Stimulus 23. No feeling for picture itself. Contents thereof not well apprehended: effort (feeling) to comprehend what I saw.

Stimulus 24. Feeling no. 5; mild intensity; lasted as long as exposure; inhibited by background. Association with Buffalo Bill, and picture of him that I had in childhood (these came up mostly after card was removed from view).

Stimulus 25. No feeling during exposure. Perception clear. A feeling has arisen from memory of stimulus.

Stimulus 26. Feeling mixed of 3 and 5. Almost simultaneous with exposure. Sharp contrast with feeling of background which inhibited that of 26.

Stimulus 27. Vivid perception (color) and yet no feeling until after the exposure.

Stimulus 28. Feeling no. 3 intense (or vivid) inhibited background for a short time.

Stimulus 29. Clear vision but no feeling.

Stimulus 30. Clear vision, feeling no. 6 (depression). Inhibited instantly by background.

Stimulus 31. Not clear vision and no feeling (except, as always, in recall).

Stimulus 32. Clear vision, feeling no. 3.

Stimulus 33. Clear vision, feeling no. 4 (remarkably indifferent sensation).

Stimulus 34. Feeling no. 1, rather intense, arose instantaneously and seemed to persist, coloring the background with feeling-tone.

Stimulus 35. Feeling no. 3, moderately intense, arose as background was being exposed and inhibited feeling of latter for a moment.

Stimulus 36. Feeling no. 5, mild, but it inhibited background for a short time.

Stimulus 37. Feeling no. 2 (weak) arose after background had been seen.

Stimulus 38. Feeling no. 6, brief, not intense, and inhibited by background.

Stimulus 39. Feeling no. 2, of mild intensity, arose slowly, but exposure was long and feeling came during exposure. Was inhibited at once by background.

Stimulus 40. Feeling no. 5 (depression?). In all these cases the background cuts off the previous perception and feeling.

Stimulus 41. Clear vision; feeling no. 6, with pleasant associations.

Stimulus 42. Perception not clear: feeling-tone no. 1 attaching to memory image.

Stimulus 43. Feeling no. 2, relaxation, moderately strong, inhibited by background.

Stimulus 44. Mild feeling of tension.

Stimulus 45. No feeling during exposure. From memory image a mild no. 3, alternating with feeling from background.

Stimulus 46. No feeling during exposure, but faint perception: fairly strong but indescribable feeling attached to memory image.

Stimulus 47. *Loathing*, very strong, but not the same as feeling no. 7. Arose instantaneously and persisted after exposure ceased.

Stimulus 48. Feeling no. 5 during exposure and increase to 6 and 7 after exposure (attached to memory image). A slight bodily tendency to shudder.

Stimulus 49. Disgust, intense: not same as feeling no. 7. Instantly and persistently felt. Contraction of the diaphragm.

Stimulus 50. Feeling no. 6, with a rather strong sensation of revolt in the stomach. Inhibited background for a moment and persisted for a considerable time longer.

Stimulus 51. Feeling no. 2 on first glancing, changing to no. 5 as (during rather long exposure) my attention rested on lesions of the skin.

Stimulus 52. Feeling no. 6 moderately strong. Disgust besides; organic sensations in lower part of trunk. All pretty quickly inhibited by background.

Stimulus 53. Moderately strong, instantaneous, and inhibiting background, cringing feeling; reaction in throat.

Stimulus 54. Feeling no. 7 strong, instantaneous and inhibiting background; reaction in throat.

Stimulus 55. The disagreeable fact not obvious on first glance; it developed later (from memory image), after background shown, and had a feeling-tone no. 7, rather mild.

Besides simple pleasantness and unpleasantness, *H* records various feelings; as, dejection, depression, massiveness, tension, relaxation, restfulness, loathing, a certain indescribable feeling. These are, however, rather emotions than simple af-

fections, such as we should expect to arise from the nature of some of our stimuli, and as we infer from accompanying reactions in throat and chest, contraction of diaphragm, revolt in stomach, contraction in back of mouth, etc. Or they may, perhaps, be simply complexes of organic or kinæsthetic sensations. Other observers also recorded these feelings and reactions, but far less frequently, except *S*, who is very liable to bodily reactions. *S* recorded, besides the reactions stated above, such things as a tendency of the whole body to a forward motion with involuntary 'ah!' — surprise; opening mouth, as if to speak or about to ask a question — wonder; shrinking — depression; shrinking of entire body — utter disgust; wrinkling or knitting brow and twitching mouth — shudder; expanding of whole body — moderately pleasant; closing of mouth and deep wrinkling of forehead — very disagreeable; tendency to raise left arm at very moment of exposure — distinct surprise at the blackness of the general impression; wide opening of eyes — after excitement; backward and contracting motions of entire body — very unpleasant and disgusting; slight forward movement of body — slightly pleasant; opening of eyes and exclaiming 'ah!' — very pleasant; tendency to smile — moderately pleasant; 'sour' reaction all over — very unpleasant and disgusting; reaction by certain finger movements — curiosity; raising of eyebrows to give close attention — wonder; etc. There are a few cases of mixed feeling mentioned in the records of *H*, *F*, *D* and *T*. Cases of affective change with change of the exposure time are noted in all the observers' records and with nearly every stimulus. More particularly, all agree that the transition from the state of no feeling to nos. 3 and 5, and thence to other steps in either direction, is definitely observable, and that at the region near no feeling and the next steps our gradations are not fine enough to express affective discrimination. Thus they often speak of 4.5, 3.5, 3.2, 3.7, etc. Finer discrimination of this sort was not recorded by *H* and *W* because they thought that the graduation should be given in the seven steps as prescribed. *T* and *B* observed that in most cases a certain process of mental excitement intervened between the stage of no feeling and the next affective stage; this they called

a 'purely indifferent feeling.' The period of this feeling was usually very short, and it was liable to be overlooked.

H seems to believe that each of the seven steps has its own intensity and vividness; he speaks, for instance, of 'Feeling no. 1 aroused faintly'—st. 14; 'Feeling no. 3 rather strong'—st. 20; 'Mild intensity of feeling no. 1'—st. 22; 'Feeling no. 2 very faint'—st. 18. But the observer did not seem sufficiently to pay attention to the influence of organic sensations and other sensational and apperceptive complexes upon the affective judgment. The differences in these factors are too often confused with alleged qualitative differences in simple affections, while in reality the latter may be quite homogeneous. Moreover, only three similar cases are recorded in all the reports of the other observers. At any rate, the evidence is not conclusive.

What all observers became surprisingly certain of is that our time-sense for affection is exceedingly definite. They could clearly trace the manner of the appearance and cessation of affection in terms of quickness, duration, and the temporal relation of the affection aroused by the stimulus to that of the background; thus they tell how it quickly appeared, or how it slowly disappeared, or how long it lasted, or they observed "the feeling came long after exposure," or "it came just at the end of the exposure," or "it came after the background was exposed," or "the feeling was inhibited for a time by the background," or "it instantaneously inhibited the feeling from the background," or "it arose instantaneously and persisted after exposure ceased," etc. Observer *T* noted that the feeling had time to reach a constant level, and that there was more or less interval during which inhibition existed. These observations seem to warrant the conclusion that affection or feeling is identical in temporal definiteness with sensory experience; and in this connection we may repeat our previous conclusion that the affective reaction-times and their variations are of the same order as those of the sensory reaction. The affective times are, however, always more or less longer than those of the cognitive reaction.

II. Reaction Experiments with Simple Colors.

The experiment reported in the first part of Section I. was made with combined color impressions. It seemed desirable to supplement this by an experiment with simple color impressions. Out of the Milton-Bradley color series, 28 colors were selected, and from these there were rechosen, as the permanent stimuli, the six: I., red (R); II., green (G); III., violet blue (VB); IV., blue violet (BV); V., violet shade 1 (VS1); VI., engine colored paper 7, with the view that colors very pleasant, very unpleasant, and somewhat variable in affective quality, as well as the two colors most widely separated in the range of reaction-time, should be included in these 6 stimuli. The selection was made on the basis of preliminary experiments with the 28 colors, performed with three observers who did not take part in the regular experiments. The other 22 colors were employed to introduce a variety in the stimuli, and with a view to the avoidance of any possible habituation. The times of reaction to these colors were not counted in the result. With each of the 6 colors, 20 affective reactions, and the same number of cognitive reactions were taken with the same stimuli for the observers *P* and *G*. For another observer *R*, 15 affective reactions and an equal number of cognitive reactions were taken with each of the 6 colors. A set of experiments comprised 26 colors, 6 of which were selected from the extra 22 colors, and distributed among the rest. The order of presentation, and the choice of extra stimuli were determined by chance.

The apparatus used was the vernier chronoscope,[1] model II., and the Wundt tachistoscope.[2] The whole frame of the tachistoscope was covered in front by a sheet of gray cardboard. The cardboard had a window (4 × 4 cm.), the lower end of which was 1 m. 16 cm. distant from the floor. A strong cardboard was inserted between the two pillars to stop the fall-screen, in which a colored paper mounted on a cardboard was placed. The screen was suspended by a pair of electromagnets at such a height that the color appeared at the moment it began to fall. The electromagnets and the chronoscope formed a circuit through

[1] E. C. Sanford, *Am. Jour. Psy.*, XII., 1901, 592.
[2] J. Zeitler, *Philos. Studien*, XVI., 1900, 381.

wires and a storage battery, which on the depression of the key was broken at the same time that the long pendulum was released.

The observer was instructed to react at the moment of the appearance of the affection, and to record his judgment in terms of P–U. He was also given general directions for the performance of the cognitive reaction to the colors. In the actual experiment, the observer sat at a distance of 1.5 m. from the window, and the experimenter standing by the tachistoscope said 'Ready,' whereupon the observer adjusted his hands to the keys. After about 3 seconds, and at the signal 'Now,' the observer pressed the key with the forefinger of the left hand, to start the long pendulum, and after the required experience pressed the key of the short pendulum with the forefinger of the right hand. The experimenter counted off the swings of the two pendulums in the usual way. The experiments were made during the months of March, April and May, 1908. They were performed in ordinary diffuse daylight; every care was taken to keep the light as constant as possible, by the adjustment of white curtains at the windows of the room.

The observers were Miss M. G. Rand (*R*), Dr. W. H. Pyle (*P*), and Dr. L. R. Geissler (*G*). *R* had had two years of laboratory training in psychology; *P* and *G* are assistants in the psychological laboratory. *G* had already taken part in extended affective studies. Only a few preliminary experiments were made for all observers, just enough to let the observers adapt themselves to the experimental conditions, with a view to the comparison of the variations due to the influence of practice upon affective and sensory reactions.

In the following Tables I., II. and III., the Roman figures in the first vertical column indicate the order of the series, and the average in each series is based upon 5 reaction-times with one and the same stimulus. The reaction-times in series IV. for *P* and *G* were taken under entirely different instructions. In this series the observers were requested to take a perceptive attitude, an attitude favorable to the determination of the quality and intensity of the stimulus, and to react when the affection naturally appeared in spite of that sensory attitude (which

TABLE I.

OBSERVER G. UNIT, $\frac{1}{100}$ SEC.

Series.		Affective Reaction Times.								Cognitive Reaction Times.							
		R.	G.	VB.	BV.	Vsi.	7	Wrong.	Av.	R.	G.	VB.	BV.	Vsi.	7	Wrong.	Av.
I.	Range	126–190	112–128	90–122	96–140	108–126	100–142			40–49	40–54	41–54	46–54	46–54	43–48		
	AV.	149	118	109	119	117	117	1	121.5	46	47	46	50	50	45	2	47.3
	MV.	21	7.0	10	14	8.0	14			3.7	5.0	5.0	2.7	2.7	1.8		
II.	Range	108–128	84–118	88–110	98–114	92–110	90–108			42–50	36–50	40–50	43–51	40–48	40–44		
	AV.	115	101	102	107	103	95	1	103.8	45	41	45	47	43	42	1	43.8
	MV.	5.3	8.0	6.1	5.6	5.0	6.0			2.3	4.2	3.7	3.0	2.7	1.3		
III.	Range	105–126	84–115	89–110	98–112	94–113	92–110			42–51	38–53	42–52	42–49	42–50	40–46		
	AV.	114	103	101	107	104	99	1	104.7	45	42	45	46	45	43	0	44.3
	MV.	6.1	8.2	6.3	6.5	5.3	7.0			2.4	3.4	3.2	2.9	2.3	1.8		
IV.	Range	98–103	96–110	110–114	100–118	94–113	88–93			42–50	39–54	41–51	43–50	41–51	42–48		
	AV.	100	103	112	109	104	90	1	103.0	44	42	44	46	47	45	1	44.7
	MV.	1.2	5.2	1.1	6.5	5.2	1.1			2.3	3.5	3.3	3.0	2.8	2.2		

TABLE II.

OBSERVER P. UNIT, $\frac{1}{100}$ SEC.

Series.	Affective Reaction Times.									Cognitive Reaction Times.							
		R.	G.	VB.	BV.	Vsi.	7	Wrong.	AV.	R.	G.	VB.	BV.	Vsi.	7	Wrong.	AV.
I.	Range	84–120	92–130	90–110	70–120	98–144	84–130	2	103.7	44–57	42–52	41–52	40–52	41–56	44–51		
	AV.	96	107	101	100	117	101			49	48	48	48	47	48	2	48.0
	MV.	8.7	12	6.0	17	15	17			5.0	4.0	4.3	4.0	6.0	3.0		
II.	Range	62–86	53–76	60–66	60–84	63–90	58–80	1	70.0	41–57	40–52	47–52	39–52	41–56	44–50		
	AV.	78	65	64	68	79	66			48	45	49	46	48	47	0	47.2
	MV.	8.0	7.2	2.4	6.8	7.8	6.0			6.3	5.0	1.5	5.0	4.0	2.3		
III.	Range	61–86	53–74	60–67	61–82	64–90	58–72			41–55	40–54	46–51	39–52	42–56	42–48		
	AV.	76	64	64	69	79	64	1	69.3	47	45	48	46	49	46	1	46.8
	MV.	7.8	7.1	2.6	7.0	8.0	5.1			5.6	4.8	1.7	4.8	4.4	3.2		
IV.	Range	92–104	84–88	90–94	92–99	92–118	92–98			42–55	41–54	44–50	41–55	41–54	42–49		
	AV.	95	86	91	95	103	95	1	94.2	47	46	47	47	49	46	1	47.0
	MV.	6.3	1.3	1.7	2.7	9.0	2.3			5.5	5.0	3.0	5.0	4.6	3.0		

TABLE III.

OBSERVER R. UNIT, $\frac{1}{100}$ SEC.

Series.		Affective Reaction Times.								Cognitive Reaction Times.							
		R.	G.	VB.	BV.	Vsi.	7	Wrong.	Av.	R.	G.	VB.	BV.	Vsi.	7	Wrong.	Av.
I.	Range	200–348	126–210	152–174	102–342	200–270	180–220	3	210.3	33–40	26–36	35–41	32–36	35–40	27–34	2	34.8
	AV.	274	168	163	222	235	200			36	33	37	34	38	31		
	MV.	49	14	10	56	23	13			2.3	4.3	2.7	1.3	1.3	2.7		
II.	Range	44–56	41–49	45–50	46–50	40–50	46–53	1	47.3	32–40	27–32	34–38	30–34	36–45	27–32	1	34.3
	AV.	50	44	47	48	45	50			35	32	36	34	38	33		
	MV.	4.0	3.7	2.0	1.3	3.3	2.3			2.5	2.6	1.4	1.4	3.7	1.6		
III.	Range	44–54	41–50	43–48	44–48	42–54	44–50	1	46.8	32–41	28–33	33–38	32–36	36–44	28–32	1	34.3
	AV.	49	45	45	47	47	48			36	32	35	35	38	32		
	MV.	3.9	3.8	1.5	1.8	3.6	2.3			2.9	2.8	1.3	1.8	3.5	1.8		

seemed to represent the more common state of affairs in ordinary life); while in all other series for *P* and *G* the attitude was purely affective, *i. e.*, a receptive attitude towards the affective quality.

Inspection of these tables shows that the times of affective reaction are decidedly longer than those of cognitive reaction. The MV of the affective reactions is also larger than the MV of the sensory, except in series IV. The times in IV. for *G* are practically the same as those in II. and III.; while the times in IV. for *P* are much larger than those in II. and III., and stand between the times in these series and in series I. In general, however, the mean variations in IV. are for both observers much smaller than those in the other series. If we take the percentages of the mean variations in terms of the averages, they are smaller even than those of the corresponding series of cognitive reactions. The ranges in IV. for both *P* and *G* are very irregular, and are similar in their mode of irregularity to the ranges in series I. The averages in I. are larger than those in the other series, especially for *R*. The longer times and the irregularity in I. are probably due to the observer's comparative helplessness in passing affective judgments, and to the fact that she availed herself of various secondary criteria, — a fact clearly shown in the introspective records of the first 30 affective judgments. General introspective remarks which were made at the end of series I. are as follow: "In general, judgment was difficult, and it was hard to come to a final conclusion. I hardly ever pass judgment immediately, and am usually uncertain of final judgment." Between series I. and II. there were 6 reaction times, one for each stimulus, which were isolated from those of both I. and II. Taking the red first they are: 94, 82, 88, 108, 92, 92; and when *R* was asked to tell the nature of the judgment in these reactions, she stated: "Judgment was easy and quite immediate, but not satisfactory, as in many cases it had changed while I was reacting." At the beginning of series II., the observer seemed to have learned entirely to give up her reflective attitude, and the very same stimuli which were formerly judged by their associates are now ranked in terms of their intrinsic pleasantness or unpleasantness. The sudden decrease

in the times in II. is the effect of this radical change. The times in III. do not greatly differ from those in II. At the end of series II. the observer made the following general observation: "Judgment was very easy and perfectly immediate. There was distinct pleasantness or unpleasantness accompanied sometimes by organic sensation as color was presented. This is the first time I have been able to react on the feeling before first naming the color that appeared." At the end of the last series, when the observer was asked to describe her affective reaction in comparison with the cognitive reactions during the series II. and III., she stated: "When reacting for perception, my attitude is more attentive. I am actively looking to see something and expecting to do something. During the affective reaction, my attitude is more quiet. I am waiting to receive the stimulus and note its effect. In neither case is there any attempt to speculate on what is going to appear. In the perception reaction, I press the key as soon as I have noted the color, and there is absolutely no feeling of *P* or *U* unless I deliberately look again at the color. In the affective reaction, when the color is pleasant, there is a distinct feeling of 'lightening' of the eyes; when unpleasant, a kind of sinking feeling and a bodily relaxation."

The times in II. and III. for all three observers are much shorter and are quite constant. One might be tempted to explain this by a possible habitual association, but there was nothing of this kind in evidence. For when *G* was requested to give an account of the sudden decrease of the times from his introspective observation, he stated: "Times of reaction seemed to be faster because I could more easily recognize my own state of affection, could tell better which way I felt about certain colors. It was not, it seems to me, a matter of associating a certain color with a certain previous affection or rather with the idea of such a previous experience. The greater ease of telling my affection showed itself also in making finer distinctions in the degrees of pleasantness or unpleasantness. Besides, the reaction with the second pendulum is much more automatic, takes no conscious effort and no innervation. In some of the older series I had sometimes to remind myself while looking at

the color that I must now react to it. Thus practice seems to have entered in two different ways: greater familiarity with certain states of feeling and hence faster recognition, and more automatic functioning of the reacting finger. I don't know of anything else that might have entered in."

The other two observers agreed with the above statements.

The absolute times of the affective reaction, even in II. and III., are longer than those of the cognitive reaction not only of the corresponding series but also of the other two series. If, however, we take the relative percentages of the individual ranges and of the mean variations, the figures for the affective reaction are of the same order as those for the cognitive reaction, as is seen in the following table:

	Percentages in Affective Reaction.						Percentages in Cognitive Reaction.					
	R.	G.	VB.	BV.	Vsr.	7	R.	G.	VB.	BV.	Vsr.	7
R	12	22	9.0	14	23	28	15	18	12	14	28	22
	3.3	8.0	3.8	4.8	8.0	7.7	3.7	8.7	5.1	5.9	8.0	9.2
P	12	40	34	24	41	41	11	35	33	14	34	33
	4.1	11	10	8.0	10	10	3.5	16	10	7.0	12	9.0
G	24	37	14	20	20	20	24	40	17	15	21	19
	6.2	7.9	6.1	7.1	5.4	5.1	7.1	8.0	6.3	4.2	5.3	5.1

In this table, the figures in the first horizontal row for each of the three observers give the percentages of the relative variation of the individual ranges, and those in the next row give the percentages of the averages to the mean variations, in series III. The corresponding percentages to be obtained from series II. also show relative variations of the same order. If we average the averages of series II. and III., for the sake of a rough comparison, we find:

	Sensory.	Affective.
R	34.3	47.1
P	47.0	69.7
G	44.1	104.3

The cognitive reaction-times of all three observers, especially of the latter two, are longer as compared with the typical times[1] of earlier studies. This is probably due to the instruc-

[1] E. B. Titchener, 'Zur Chronometrie des Erkennungsactes,' *Philos. Studien*, VIII., 1893, 141.

tion given as to the stage of the cognitive process at which the reaction should be made; the observers were told to react at such a cognitive moment that they should be able to report the general quality of color after the reaction movement was made, although actually the report was not required. It seemed fair, for comparison with the affective times, to give their 'Aufgabe' for the cognitive reaction, since in the affective reaction the observers were required to record their judgments in terms of P–U. The affective reaction-times of *G* are strikingly longer than those of the other two observers. This is probably partly due to individual difference, and partly to *G*'s extremely passive attitude in the reaction; for when asked to describe his affective reaction, he stated: "When I am to make an affective reaction I must be unconscious of my body and even of the purpose of the experiment, the idea of the motive has to be as vague as possible. I rely on the very vague pressure sensations coming from the fingers touching the keys to remind me of the reaction. Really, how the second reaction ever takes place I am not able to say, because the motive is not conscious. Hence I catch myself sometimes suddenly arousing to the consciousness 'now I must move that key.' . . . I could not really tell what my attention is on before reacting, probably on the color more or less, but I never thought of this fact until this moment."

There was no single case, in the reaction experiments, when the affection appeared first in consciousness, as the herald of the connected sensory quality. This result is contrary to Wundt's recent opinion[1] and to that of certain others. That the formation of an affective consciousness requires a longer time than that of a sensory consciousness is not only indirectly proved by the reaction experiments, but directly by the introspective evidence given by our observers, and by the evidence of the direct reaction method with which expertments were made in the Harvard laboratory (Section I.). Another result which has been brought out in the present experiment is that the relative variability of the affective reaction-times follows the same rules as that of the cognitive reaction-times, so that the affective proc-

[1] Cf. the writer's article: 'Contributions to the Study of the Affective Processes,' *Am. Jour. Psy.*, XX., 1909, 181.

ess is undoubtedly identical with the sensory in that respect, in spite of its difference from the latter in the need of longer times. Moreover, the affective times of *R* are of almost the same order as the cognitive reaction-times, and it is possible that, as the observer became more familiar with affective experience, the times might more nearly approach those of the sensory reaction.

III. Reaction Experiments with Tones.

In the field of sensory reaction, it is already established that the times differ with different sense departments. Whether the same thing holds for the affective reaction is not yet known, except in the cases of affective reaction with visual and cutaneous impressions.[1] The time-relations of affection to sensation are also known in those two senses. The desirability of systematic completion led us naturally to further study of the same problem with tones; we assumed the applicability of the reaction method in this field. Meanwhile we had also another part-problem in view, that is, the time-relation of the affective processes to their physiological expressions. We therefore resorted to the graphic method. However, a full description of the experiments and presentation of their results would deviate too far from the main aim of the present study; they are, therefore, omitted in this article.

The apparatus used in the main work were a chronometric interrupter manufactured by G. Hasler, Bern; a clock-work kymograph made by C. H. Stoelting; and a piano as the source of stimulus. An electromagnetic time-marker formed a circuit with the interrupter through wires, a storage battery, needles attached to the interrupter, and the mercury contained in small cylindrical glass vessels under the needles. To maintain the vibration of the interrupter, another circuit was made between a pair of larger electromagnets above the interrupter and the direct-current switch in the wall-box of the experimenting room. A Nichols tinned iron rheostat was inserted in the circuit to regulate the voltage. The distance between the needles and the mercury surfaces, and the distance between the electromagnets and the interrupter can be so adjusted that the circuit

[1] *Ibid.*, pp. 187–193; and Sections I. and II. of this paper.

through the time-marker closes, while the circuit through the larger electromagnets is broken, and conversely. The vibration rate of the interrupter ranges between 10 and 60 in a second. In the present experiment, the point of 25 vibrations was selected, but with the highest speed of the drum it was possible to count .02 sec. without fractionating the curve. The stimuli were tones from the piano, under whose keyboard was laid a rubber tube. The one end of the tube was connected with a Marey tambour, and its writing lever marked a signal on the smoked paper of the drum as soon as a key was struck, so that the moment of stimulation was known. The observer's reaction to the stimulus was registered by an electromagnetic signal, which formed another separate circuit through wires, a storage battery, and a double contact electric key. Occasionally, tests were made to determine possible time-errors in the signal of stimulation, by bringing the electric key near and parallel to the piano key, and by striking the note and pressing the key button at the same time, in order to make a comparison of the time-relation of the two signals. There was, however, no definite time error; and if there was any error at all, it was a negligible quantity. Every care was taken to make the ends of these three pointers lie in one and the same vertical line on the smoked paper.

The observer was given general directions for the performance of the cognitive reaction[1] to tones. In the affective reaction he was required to react at the moment of the appearance of the affection, and to record his judgment in terms of P–U. He was also told to make another reaction, at the cessation of the tone or the affection as the case might be. In a concrete experiment, the experimenter sat before the piano, and at the 'Ready' the observer closed his eyes and adjusted the forefinger of the right hand to the button of the key. As soon as the observer seemed ready, the experimenter called 'Now,' and struck a note. After the second reaction, he stopped the drum, and numbered the smoked paper. The experiments were made during the months of June, 1908, to January, 1909, with the intermission of a greater part of the summer vacation. The following observers served in the experiments: Miss M. C. West (*W*),

[1] E. B. Titchener, *Exp. Psychol.*, II., i., 1905, 187.

Dr. Geissler, Dr. Pyle and Miss E. M. Kitch (*K*), a graduate of Oberlin College. *W* had already taken part in extended affective studies.

Out of the 46 notes, striking out the first 5 low tones, C_1, D_1, E_1, F_1, G_1, and the last 6 high tones, a^3, b^3, c^4, d^4, e^4, f^4, we selected 7 low tones, A_1, B_1, C, D, E, F, G, 7 high tones, a^2, b^2, c^3, d^3, e^3, f^3, g^3, and the 7 tones of the middle part, a, b, c^1, d^1, e^1, f^1, g^1. Out of these 21 tones, the 9 tones A_1, D, G, a, d^1, g^1, a^2, d^3, g^3 were rechosen as the permanent stimuli; the other twelve tones were employed to introduce a variety of stimuli, with a view to the avoidance of possible habituation. With each of the 9 tones, 20 affective reactions and an equal number of cognitive reactions were taken with the same stimuli. A set of experiments comprised 22 stimuli, 4 of which were selected from among the extra 12 tones, and distributed among the set. The reaction-times of these extra stimuli were not counted in the result. The order of presentation, and the choice of extra stimuli were determined by chance. This rule was kept throughout all the experiments with *W*, *K* and *G*. With *P*, 30 affective and 40 cognitive reactions were taken with each of the 9 tones. A complete set of experiments comprised 50 stimuli, 30 of which were presented for sensible, and 20 for affective reaction. Care was taken to distribute the 9 tones evenly, and to utilize them all in the affective work. The 50 stimuli were so arranged that the same tone was never presented twice in succession, for the two kinds of reaction; and the order of presentation was reversed from set to set. A half set, 25 reactions, was taken in the experimental hour. Since all the observers had already had considerable experience in reaction experiments, we did not give more than one set of 22 reactions for preliminary practice. With observer *P*, only a few preliminary experiments were made for each of the two kinds of reaction, to let the observer adapt himself to the new experimental conditions with a view to the comparison of any possible variations due to the effect of practice upon affective and cognitive reactions.

Tables I., II. and III. give the results of 360 reaction-times obtained from the observers *G*, *W* and *K*; 180 times of cogni-

tive, and an equal number of affective reactions for each observer.

TABLE I.

OBSERVER G. UNIT, $\frac{1}{100}$ SEC.

Stimulus.	Affective Reaction Times.				Cognitive Reaction Times.			
	Range.	Average.	MV.	Wrong.	Range.	Average.	MV.	Wrong.
A_1	73–96	89	8.2	1	34–42	38	3.0	0
D	68–94	85	11.0	0	35–44	40	3.1	1
G	60–87	82	10.7	0	26–36	32	3.0	0
a	59–89	73	8.5	0	26–36	30	3.6	1
d^1	57–78	68	8.8	1	27–42	36	4.0	0
g^1	60–78	69	6.3	1	31–38	35	3.5	0
a^2	76–94	82	8.0	1	27–38	31	4.0	0
d^3	54–80	72	9.3	0	25–34	30	3.1	0
g^3	80–92	85	3.2	1	35–42	38	2.7	1

TABLE II.

OBSERVER W. UNIT, $\frac{1}{100}$ SEC.

Stimulus.	Affective Reaction Times.				Cognitive Reaction Times.			
	Range.	Average.	MV.	Wrong.	Range.	Average.	MV.	Wrong.
A_1	56–76	65	7.0	1	32–47	41	4.9	2
D	58–74	67	5.0	1	35–45	40	4.0	1
G	59–87	77	7.4	0	32–44	38	4.2	1
a	47–63	53	6.0	1	30–44	36	4.0	0
d^1	48–58	53	5.0	2	37–44	41	3.5	1
g^1	58–89	76	9.9	1	30–44	37	4.0	1
a^2	54–70	63	5.7	1	37–41	39	2.0	1
d^3	59–64	62	2.0	0	38–48	42	3.5	2
g^3	49–57	53	5.1	1	36–42	39	2.3	1

TABLE III.

OBSERVER K. UNIT, $\frac{1}{100}$ SEC.

Stimulus.	Affective Reaction Times.				Cognitive Reaction Times.			
	Range.	Average.	MV.	Wrong.	Range.	Average.	MV.	Wrong.
A_1	52–73	63	7.0	1	30–42	37	4.0	1
D	66–86	76	8.1	2	35–45	42	4.0	1
G	60–86	76	7.5	1	26–42	33	3.9	1
a	60–80	69	8.2	1	38–46	40	3.4	1
d^1	64–76	71	4.0	0	25–40	33	3.9	1
g^1	45–76	61	7.9	0	29–94	38	4.3	1
a^2	56–80	69	8.4	0	38–43	41	2.5	0
d^3	58–74	68	6.7	1	30–45	41	5.2	1
g^3	54–70	58	6.2	1	28–38	33	2.0	1

The tables show clearly that the times of affective reaction are decidedly and uniformly longer than the times of cognitive

reaction.[1] The MV of the affective reactions is also larger than the MV of the cognitive reactions; a single exception occurs for *W* with the stimulus d^3. In general, however, the individual ranges of the affective reaction-times are of the same order as those of the cognitive reaction-times in their relative variation; and the total range of cognitive variations, from 20 per cent. with g^3 to 41 per cent. with a^2 for *G*, from 11 per cent. with a^2 to 47 per cent. with *a* for *W*, and from 13 per cent. with a^2 to 61 per cent. with *g* for *K*, nearly coincides with the affective limits 15 per cent. (unpleasant) and 50 per cent. (pleasant) for *G*, 9 per cent (distinctly pleasant) and 53 per cent. (slightly pleasant) for *W*, 19 per cent. (very pleasant) and 68 per cent. (pleasant) for *K*. The individual relative values of the mean variations to the averages are also of the same order; and the mean variations corresponding to the above percentages are as follows: 7 and 13 per cent. for *G*, 5 and 11 per cent. for *W*, 6 and 12 per cent. for *K*, in the cognitive reactions; 4 and 12 per cent., 3 and 13 per cent., 6 and 13 per cent., in the affective reactions.

Table IV. gives the results of 270 affective reaction-times and 360 cognitive reaction-times. The Roman figures in the second row indicate the order of the series, and the figures under each series show the range, average and its mean variation of 10 reaction-times with the same stimulus. The average in the third row from the last is the average of averages in each of three series in successive order.

The general results are the same as those of Tables I., II. and III. Taking the figures in the third series, the total range of cognitive variations, from 35 per cent. with *G* to 64 per cent. with g^1, stands nearly on the same level as that of the affective limits 26 per cent. (very pleasant) and 53 per cent. (barely pleasant). The corresponding percentages of the mean variations are 9 and 11 on the one hand, 8 and 13 on the other. The results in the first and second series do not greatly differ from those of the third series. The average of the first series is

[1] G. Martius states that the reaction-times for high tones are shorter than those for low tones (*Philos. Studien*, VII., 1891–92, 470–480). The times in the above tables show no trace of such difference; probably it has been swamped in our larger cognitive times.

larger than those of the two other series; the decrease of the time is probably due to the influence of practice. It is, however, so slight that the times in I. show no trace of isolation from

TABLE IV.

OBSERVER P. UNIT, $\frac{1}{100}$ SEC.

		Affective Times			Cognitive Times.			
		I.	II.	III.	I.	II.	III.	IV.
A_1	Range	48–58	49–58	47–59	27–40	28–40	25–39	25–39
	AV.	52	51	52	30	29	30	30
	MV.	4.0	3.8	4.0	3.6	3.4	3.1	3.1
D	Range	44–65	45–65	44–64	26–40	27–42	27–40	25–40
	AV.	56	54	55	31	30	31	29
	MV.	6.1	6.0	6.0	3.5	3.5	3.0	2.6
G	Range	40–62	40–60	40–60	27–38	26–36	26–35	26–36
	AV.	50	49	49	29	29	28	28
	MV.	5.1	4.8	5.0	2.6	2.4	2.5	2.6
a	Range	55–82	56–79	58–80	26–40	28–41	26–40	26–39
	AV.	65	63	63	33	32	31	31
	MV.	7.0	6.8	6.8	3.6	3.4	3.2	3.2
d^1	Range	50–76	51–77	49–74	24–38	25–39	24–37	25–36
	AV.	63	63	61	30	29	29	28
	MV.	7.4	7.0	7.0	3.0	3.2	3.0	2.7
g^1	Range	44–64	45–65	44–63	24–38	24–40	25–41	24–38
	AV.	54	54	52	28	29	28	27
	MV.	6.5	6.6	6.2	3.0	3.1	3.0	2.8
a^2	Range	54–82	52–79	51–76	25–39	26–38	24–35	24–37
	AV.	66	64	63	31	30	30	29
	MV.	8.6	7.9	7.8	3.4	3.2	3.2	3.2
d^2	Range	50–78	50–75	51–78	24–34	26–35	25–34	25–36
	AV.	62	60	60	29	28	28	27
	MV.	8.1	7.9	7.8	3.0	2.8	2.7	3.0
g^2	Range	52–76	53–75	53–76	28–42	29–42	28–41	24–40
	AV.	63	61	60	36	35	35	34
	MV.	6.0	6.0	6.2	3.9	3.7	3.8	3.5
Average		59.0	57.7	57.0	31.0	30.1	30.0	29.0
P.E. of AV.		±4.01	±3.80	±3.54	±1.66	±1.42	±1.49	±1.49
Wrong		3	2	2	3	2	1	1

those in the other series. A like constancy was found with the three other observers. There is no indication of an effect of fatigue, which would show in loss of regularity and in a lengthening of time in the later series.

For the sake of a general grasp of the essential result, we give the average of averages for all four observers:

	Sensory.	Affective.
G	34.4	78.3
P	30.4	57.9
W	39.2	63.2
K	37.5	67.9

The reaction at the cessation of the tone or of the affection was required not in all, but in the greater part of the experiments. The total number of experiments in which the second reaction was made is 216: 12 cognitive reactions with each of the 9 tones, and the same number of affective reactions, for each observer. The following table gives the result:

Observer.	Sensory Duration.				Affective Duration.			
	P	*G*	*W*	*K*	*P*	*G*	*W*	*K*
A_1	337	159	246	237	218	119	237	250
D	192	118	224	218	121	114	169	173
G	190	114	189	186	112	110	89	156
a	190	101	137	132	90	100	79	189
d^1	180	93	120	120	90	97	80	100
g^1	178	93	160	171	86	96	72	246
a^2	188	90	120	140	92	95	70	188
d^3	175	91	230	252	85	90	267	316
g^3	137	92	210	215	78	94	225	233

The table shows that in general the duration decreases from the low tones to the high. The tones d^3 and g^3 are marked exceptions with *W* and *K*. However, what we are concerned with is not the relation of duration to pitch, but the relation of sensory to affective duration. For *P* the sensory duration is always longer than the affective, and in his introspective records there is no mention of a case in which affection lasted longer than sensation. For *K*, *W* and *G*, such cases are by no means exceptional, and in the introspective records they often and definitely stated their occurrence. They noted, however, that the affection attached to a kind of memorial after-image of the tone. For *W* bodily attitude seemed also to have something to do with it: "I noticed in exp. 3 and 4 that after the tone ceased I was still enjoying it, but as I noticed this the *P* seemed to resolve itself into a physical attitude — very still, breath indrawn, a sort of tickle in the chest, eyes closed, chest lifted, and a sort of

judgment without words that it was nice. It seemed to me that as long as I kept myself perfectly still and in that position I should continue to enjoy it, and then I began to be uncertain whether it was real feeling or not — I thought 'this might as well end — I'll never know — I can keep this up indefinitely' — and so I struck the key. In both cases I felt dissatisfied afterwards, and thought that the next time it happened I would keep it up, and see if I had the feeling as long as I had the attitude. So in no. 9 I held on to the feeling and attitude until I was sure the feeling was gone, but I wasn't sure when I lost the attitude, it may have been before or after or with the feeling. But the difference between this state after the feeling is gone, and the other which I wasn't sure of as *P*, makes me now certain that it was *P*, and that I could not hold it indefinitely; yet I could and did prolong it, I think, by holding the attitude — for the other times, when I gave it up, *P* ended as I struck, when it might have lasted longer, I think."

W also recorded many cases of affective change, and in such cases there was usually an indifferent state at the point of change; but the time-relations of the state could not be determined; its duration was very short, and was not registered.

Turning now to our original problem, we should say in summary that the main results of the present experiments are essentially the same as those of the last section. It remains only to remind the reader of the fact that in the affective reactions with colors, the initial irregularity in variation and the subsequent shortening of the times were striking, while in the affective reactions with tones there were no such heterogeneous variations or sudden decrease of the times.

Conclusions.

The essential conclusions to be drawn from this study and from the earlier researches connected with it are (1) that affective judgments may be and usually are as direct and immediate as the sensory judgments of psychophysics; (2) that the formation of an affective consciousness requires a longer time than that of a sensory consciousness; (3) that affective times and their variability are either absolutely or relatively of the same

order as sensory times and their variability; (4) that the method of reaction, when applied to the affective processes pleasantness and unpleasantness, has a like scope and validity as for sensory processes. More particularly, the direct reaction-method is feasible and reliable. However, the time-relation of affective to sensory process varies with the different sensory fields. The relation is most intimate in the case of cutaneous impressions, as was shown in our work with the discriminative reaction; the averages of the sensory and the affective times for an average observer being 56.8 and 73.5. There was an indication that the relation would be still closer, with olfactory stimuli, as we judged by the result of our experiments with odors. The time-relation in the experiments with colors and tones is complicated, and it is difficult to make a fair comparison (the average affective times of tones and colors are respectively 67.9 and 69.7); but in general, the affective reaction to color impressions seems most remote from the sensory in its time-relations. The times, however, vary with variation of stimulus; sensory intensity is the most important factor. This is best shown in the experiments made with illustrative cards in the dark room. The cards were adequately illuminated, and were very favorable for the arousal of affective processes, as was shown both by the observers' introspective evidence that the quality, intensity, and temporal course of the affective processes were in their case surprisingly definite, and also by the objective evidence that the affective times were so far shortened that the median, for an average observer, amounted only to 42.5. In regard to the interpretation of the results of our reaction experiments, two opinions are *a priori* possible. The one is that pleasantness and unpleasantness are the resultant of a sensation-complex or of an apperceptive combination, the range of the complex process being variable through three grades at least: sensational complex, apperceptive combination of sensation and ideas, and fusion of apperceptive combination with organic sensations. Affective arousal should then, as Münsterberg would maintain, take a longer time than sensory, since these complex processes must be formed before affection appears as a definite resultant in consciousness. The other view regards lack of clearness as

the principal criterion of affection. The delayed appearance of an affection is then due to this characteristic. The results of our experiments tell, we believe, for the second hypothesis; for affective judgments could be passed directly and immediately on the basis of the stimuli and of these only, as is proved in our earlier studies on the mechanism of the affective judgment. In the experiments with illustrative cards, cases were frequent in which the mature stage of complex apperceptive fusion had been reached in the affective judgments, and yet these did not require longer times; the averages and the medians were, on the contrary, shorter than the times of affective reaction with simpler processes.

It is, however, a question if lack of clearness in affection is absolute. It may be only relative; it need not imply the impossibility of affective attention. Discriminations in seven or even more than seven grades; the definite determination of rise, cessation, and details of temporal course; observations of intensive change with change of exposure time, and of phenomena of inhibition; and finally, the similar or identical time-relations of affective and sensory process — all these introspective descriptions and objective results may perhaps be direct measures of affective clearness and affective attention. The whole issue must, however, be left open, so far as the present studies are concerned, since an affective consciousness always includes sensory or ideal components, and what appear without analysis to be affective discrimination and affective attention may be based upon and guaranteed by these sensory or ideal concomitants.

Further light on the relation of affection to sensation can be hoped for only after serious researches have been carried out on the other criteria of affection proposed by various investigators, which have recently received review and criticism by Titchener in his *Psychology of Feeling and Attention*. What we think we have proved is that affection is different from sensation in its need of a longer time of arousal; but that it is akin to sensation in so far as affective judgments are direct and immediate, and affective times and their variability are of the same order as those of their sensory correlates.

A NOTE ON THE ACCURACY OF DISCRIMINATION OF WEIGHTS AND LENGTHS.

By PROFESSOR EDWARD L. THORNDIKE,

Teachers College, Columbia University.

It is the purpose of this note to present some new data upon the very old question referred to by the title in the particular case of weights of 100 and 200 grams and lines of 50, 75 and 100 mm.

In spite of the repeated failure of experimental researches to verify the doctrine that the larger magnitude requires a proportionately larger difference for equal discriminability, that doctrine reappears so persistently in our text-books that it may be supposed to require further refutation.

The measurements with weights comprise 16 tests by the error method with each of 72 subjects. Eight were with a 100-gram standard and 8 with a 200-gram standard. The method was to give the subject the standards and also some boxes identical with the standards, except that of course they were empty, and also a supply of lead scraps and shot. The subject filled an empty box, comparing it with the standard by lifting both simultaneously or successively as often as he chose, adding or taking out shot until he was satisfied. The experiments were conducted by Dr. Wilfrid Lay, a trained psychologist, and Mr. P. R. Dean, a student and teacher of physics. Counting of the shot was not done by the subjects and, of course, would not have been allowed. They worked in ignorance of the amounts of the errors they made. The subjects were 37 young women students of psychology and 25 high school boys.

In the nature of the case there were no important general tendencies to constant error since the subject compared his weight with the standard back and forth several times. With the 200-gram weight there was a slight tendency to a minus error because the subjects filled up *to* the weight oftener than they

over-filled and corrected. The deviation from the standard is the measure (inverse) of accuracy of discrimination.

The general tendency is for the 200-gram weight to show an error 1.585 times that of the 100. The probable Median Deviation of this result from the true general tendency is *.04*, Taking the 37 young women separately we have 1.65 (*.07*). The figures are 1.52 and (*.14*) for the 25 high school boys.

Table I. gives for the 34 women the sum of the deviations from the standard for the 100-and 200-gram weights, the ratio

TABLE I.

Individual.	Sum of Deviations.		Ratio of Error with 200 g. to that with 100 g.	Apparent Median, Constant Errors, with:	
	From 100 g.	From 200 g.		100 g.	200 g.
1	96	58	.60	2	4
2	64	93	1.45	9	— 3
3	45	94	2.09	5	0
4	37	73	1.97	3	0
5	57	88	1.54	— 6	— 4
6	48	76	1.58	— 5	0
7	21	47	2.24	0	.5
8	45	27	.60	— 6	.5
9	36	191	5.31	1.5	— 7.5
10	79	103	1.30	7.5	2.5
11	24	96	4.00	— 1.5	— 3
12	55	91	1.65	2.5	— 6.5
13	21	43	2.05	0	— 2
14	15	82	5.47	0	— 8
15	43	85	1.98	0	1.5
16	41	65	1.59	3	9
17	52	103	1.98	— 6	—12.5
18	21	46	2.19	— 1.5	— 3.5
19	28	110	3.93	1.5	— 3.5
20	75	89	1.19	3.5	— 8
21	52	160	3.08	— 2	—19
22	48	76	1.58	— 6	— 8.5
23	104	74	.71	— 3	1
24	25	72	2.88	2	— 5
25	111	118	1.06	16	— 8
26	33	55	1.67	0	— 5.5
27	48	78	1.63	2	10.5
28	37	56	1.51	3	— 1.5
29	52	77	1.48	7.5	.5
30	56	73	1.31	1.5	3.5
31	93	58	.62	.5	2
32	28	50	1.79	0	.5
33	100	214	2.14	—12	—29
34	34	58	1.71	1.5	— 1
35	68	148	2.18	3	4
36	157	169	1.08	29	— 8
37	42	25	.60	4	— 2

Median of ratios = 1.65.

of the latter to the former and the apparent constant errors for the two sets, all for each individual. The last facts are given to show the impropriety of using the deviation from an individual's own general plus or minus tendency as a measure of discrimination.

Table II. gives similar facts for the 25 boys, except that here the sums of deviations were taken from the general tendency of 198 g. instead of from 200 g. Two hundred grams would have been better to use, but as it makes no difference in the general results, I have not recalculated all the deviations.

TABLE II.

Individual.	Sum of Deviations.		Ratio of Error with 200 g. to that with 100 g.	Apparent Average, Constant Errors, with:	
	From 100 g.	From 198 g.		100 g.	200 g.
38	40	60	1.50	— 2	4.5
39	40	66	1.65	2	6.5
40	37	24	.65	— 4.5	— 4
41	35	53	1.51	1	1.5
42	65	73	1.12	7	7
43	53	264	4.98	— 6	—15
44	90	161	1.79	3	—19.5
45	103	91	.88	— 8.5	—13.5
46	44	80	1.82	— 4	— 8.5
47	63	96	1.52	6.5	—13
48	28	40	1.43	2.5	1.5
49	33	84	2.55	— 4	— 7.5
50	55	53	.96	7	0
51	34	36	1.06	— 1	— 1.5
52	113	108	.96	13	—14
53	33	61	1.85	— 1	— 1
54	46	72	1.57	— 2	— 4
55	33	80	2.43	0	1
56	62	94	1.52	7.5	5
57	36	45	1.25	— .5	— 5.5
58	49	109	2.22	0	9
59	65	138	2.12	— 7	—11
60	62	72	1.16	8	— 2
61	23	73	3.17	.5	6.5
62	79	97	1.23	— 8	— 5

Median of ratios = 1.52.

My measurements with lines comprise 60 tests with each of 37 individuals — 30 in drawing a line at one side of a 100-mm. standard as nearly as possible equal to it, and 30 in equalling in the same way a 50 mm. standard. The individuals tested were the students of psychology mentioned above, and the tests were conducted by Dr. Lay.

Table III. presents the results in the shape of (1) the sum of the deviations from the standard, (2) the general tendency to draw too long or too short lines (the so-called constant error) and (3) the so-called variable error, that is, the general tendency to deviate from the individual's own general tendency to draw too long or too short lines (the measure used for this variable error is the distance between the limits which include 50 per

TABLE III.

Individual.	A. Sums of Deviations from the Standards.		B. So-called Constant Errors.		C. So-called Variable Errors ($s \times Q$).		D. Ratios 100/50 from A.	E. Ratios 100/50 from C.
	From 50 mm.	From 100 mm.	From 50 mm.	From 100 mm.	In case of 50 mm.	In case of 100 mm.		
1	166	159	0	3.5	8	8	1.37	1.00
2	91	232	1.5	8	6	5	2.55	1.00
3	51	138	0	4	4	8	2.71	2.00
4	57	77	1	2	4	4	1.35	2.00
5	138	170	4	—2	4	6.5	1.23	1.63
6	108	359	2	12	5	10	3.32	2.00
7	90	79	—2	1	2	5	.88	2.50
8	56	130	0	3	4	6	2.32	1.50
9	110	289	2	6	5	16	2.63	3.20
10	115	242	3.5	8.5	4	5	2.10	1.25
11	80	204	2	6	5	6	2.55	1.20
12	111	234	1.5	8	5	6	2.11	1.20
13	75	124	2.5	4	4	2	1.65	.50
14	115	122	—3	2.5	4	8	1.06	2.00
15	81	86	—3	0	3	7	1.06	2.33
16	94	151	1	4	7	6	1.61	.86
17	118	135	—4	5	3	4	1.14	1.33
18	80	198	—1.5	0	4	15	2.47	3.75
19	66	148	1	4	4	6	2.24	1.50
20	79	203	.5	6	6	8	2.57	1.33
21	122	198	—1.5	—5	10	7	1.62	.70
22	45	97	2	2	2	4	1.02	2.00
23	89	113	3	3	3	4	1.27	1.33
24	253	459	8	15	5	5	1.81	1.00
25	181	220	6	7.5	5	5	1.22	1.00
26	90	193	—1	5	6	7	2.16	1.17
27	138	110	—4.5	— .5	5	8	.80	1.60
28	69	66	2	2	4	4	.96	1.00
29	76	297	—1	9.5	4	7	3.91	1.75
30	167	154	—5	1.5	10	12	.92	1.20
31	83	183	0	6	6	6	2.21	1.00
32	74	141	2	2	2	5	1.91	2.50
33	135	202	4	5	5	8	1.50	1.60
34	112	222	3	7	3	6	1.98	2.00
35	171	331	6	11.5	3	4	1.94	1.33
36	245	329	8.5	10	5	11	1.34	2.20
37	63	160	1	5.5	5	5	2.54	1.00

Medians of ratios are 1.81 and 1.33.
Averages of ratios = 1.79 and 1.42.

cent. of his records), (4) the 100/50 ratio in the case of the deviations from the standard, and (5) the 100/50 ratio in the case of the deviations from the so-called 'constant error.'

As has been pointed out by Professor Cattell, the so-called constant error is really extremely variable in the case of equalling lines. It is a result of short-lived motor or perceptual habits as well as of some persistent tendency. It is sensitive to practice. It differs enormously with individuals. The practice of disregarding it in measuring the accuracy of sense discrimination is therefore dubious. When we disregard it, we do not have left a measure of accuracy in any intelligible sense, but strictly only a measure of the *variability* of an individual in responding to the same situation.

It is not, however, my purpose at this time to interpret the errors made, but only to point out that, whatever measure one chooses to take of inaccuracy of sense discrimination, the inaccuracy is not proportional to the magnitude used as a standard. The deviations from the standard are not twice as great for the 100-mm. line as for the 50, but only one and three fourths times as great [$1.8 \pm .1$ (P.E.)]. And the so-called variable error in the case of the 100-mm. line is only one and one third times that with the 40-mm. line [$1.4 \pm .08$ (P.E.)]. If each individual's deviations from the constant error of the entire 37 are used, the ratio is still less than one and a half.

The variations of the individuals from the central tendency of the group are very wide in the case of both weights and lines. There is nothing like close clustering of the individual ratios about 1.6 in the former, or 1.8 and 1.4 in the latter case.

I attribute the results in general not to one main cause, in the shape of some one psycho-physic law, varied by minor disturbing causes, but to the influence of many specialized tendencies to response. The individual scores for the weights, coming each from only 8 measures, are subject to much variation from the totals of which they are samplings. Tests covering hundreds of trials spread over many days would reduce the individual differences in the 200/100 ratios markedly. But it is hard to believe that such would reduce them to a range much less than 190 to 130. The individual scores for the lines are more reliable and

rough calculation of their reliabilities shows the practical certainty that with complete measures there would remain a range of variation, around the 1.8, of from 1.5 to 2.3 and a range, around the 1.4, of 1.15 to 1.75.

In general the determinations of the so-called psycho-physic law have failed to find close correspondence in the different individuals measured or in the different divisions of the magnitude-series used. It is chiefly the speculative doctrine that *some* one simple equating of sensations or judgments with magnitudes judged must exist and be the main cause of our powers to judge them that has led psychologists to neglect these failures. But against such a doctrine stand (1) the facts of the changes in these powers with practice, (2) their specialization with content, and (3) the difficulty of connecting the doctrine with the known facts about the action of the nervous system, as well as (4) the direct measurement of the variations amongst individuals. The present writer believes not only that the experimental data do not give proof of the existence of any one psycho-physic law, but also that they do give proof that there is *not* any such one law.

An objection may be made to the original measurements themselves: namely, that they are extremely complex measures of discrimination resulting from all sorts of conditions. This is true, in the sense that the judgment of weight was allowed to rest upon liftings in any number, at any rate, with either hand, and that the judgments of length were allowed to rest upon data from the movements made in drawing the lines or from the sight of them at varying distances while being drawn and after completion. But it is not necessarily true if complexity means elaborateness from the point of view of the individual making the judgment or with respect to the behavior of the nervous system in making such responses. To have to lift weights at the same rate through the same distance by a time schedule may be a more complex act, because of the inhibitions involved, than the act in the case of my experiments.

But in either event the method is not really objectionable. If the law in question held for the responses when made to each single constant kind of sense datum, it would necessarily hold

for any responses to any random combination of such. The particular accuracies might vary, but the general law would appear as before. So, unless the critic can give evidence that the subjects chose specially accurate data from which to judge the 200 g. weights and specially inaccurate data from which to judge the 100 g. weights, the objection is futile.

The writer chose the method deliberately because it seems to him sure that accuracy in sense-discriminations has developed as a function of responses to concrete objects with all the available means at the animal's disposal, and that the laws regulating it will relate more closely to such instinctive responses and the habits they easily grow into than they will to the rare and artificial responses we cultivate by restricting the situation ostensibly to some one element, but really to that element in an elaborate context of distracting suggestions and inhibitions.

A RANGE OF INFORMATION TEST.

BY PROFESSOR GUY MONTROSE WHIPPLE,
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In Professor Kirkpatrick's vocabulary test, the application of which I discussed last year,[1] the list of one hundred test-words is intentionally selected by chance: some of the words, like *page*, happen to be very ordinary, every-day terms; others, like *lanuginose*, are unusual, technical terms. Knowledge of the ordinary words is, of course, common to almost all examinees: knowledge of the more unusual terms, however, depends almost entirely upon the examinee's erudition — upon the nature of his school training, his professional interests, and the quantity and type of his general reading.

I have endeavored to extend, or rather to supplement, the vocabulary test by devising a list of words that shall serve in its entirety as a measure of erudition or range of information. For this purpose the hundred test-words have been selected, not by chance, but by careful consideration, and in such a manner that each shall be representative of some specific field of knowledge or activity, in the sense that if the examinee has made himself familiar with a given field of knowledge or activity, he will almost certainly know the word selected from that field, whereas, if he has not made himself familiar with the field, he will almost certainly not know the term, or at least will not have such knowledge of it as to enable him to define it exactly. Thus, general knowledge of American history is tested by the name *Anthony Wayne*, knowledge of French by *aujourd'hui*, of chemistry by *chlorine*, of golf by *midiron*, of social usages by *R. S. V. P.*, of the technique of photography by *f-64*, etc.

Nature and Method of the Test. — For conducting the range of information test, each examinee is supplied with a printed blank[2] as reproduced herewith: he is asked to read the direc-

[1] 'Vocabulary and Word-building Tests,' PSYCH. REV., 15, March, 1908, 94–105.

[2] These blanks may be had of C. H. Stoelting, 12 S. Green St., Chicago.

tions through twice before marking the words, and his attention is called to the request for definitions that follows the test-words. There is no time restriction.

Name..... Date.....

INFORMATION TEST.

Below are 100 words, phrases, or abbreviations, largely technical, which are designed to test the range of your information. Consider each one carefully, and place *before* it one of these four marks:

(1) The mark **D** if you could *define* it as exactly as words are ordinarily defined in the dictionary.

(2) The mark **E** if you could *explain* it well enough to give some idea of its meaning to one who is not familiar with it, though you could not give an exact definition that would satisfy an expert.

(3) The mark **F** if the word is merely roughly *familiar*, so that you have only an indefinite idea of its meaning and could not use it intelligently.

(4) The mark **N** if the word is entirely *new* or unknown to you.

When you have finished, count the marks, and fill out these blanks:

D	E.....	F.....	N.....
ageratum	cleistogamous	infusoria	puer
amphioxus	cosmogony	intaglio	pyramidal tract
amphora	cotangent	Kepler's law	quadratics
annealed	dibble	kilogram	rococo
Anthony Wayne	dietetics	kinesthetic	R. S. V. P.
apocalypse	dryad	kinetic	scherzo
architrave	electrolysis	Les Misérables	semaphore
aujourd'hui	Elohim	linotype	simony
Babcock test	entrée	logos	spoils system
base-hit	Eocene	luff	Stoicism
Bernard Shaw	Euclid	Malthus' law	synecdoche
Bokhara	*f*—64	metacarpal	testudo
Braille	f. o. b.	midiron	tort
call-loan	gambit	Millet	trephine
calorie	gasket	mitosis	triangulation
cantilever	glycogen	morgen	trilobite
Cædmon	gneiss	nada	triple-expansion
catalepsy	golden section	natural selection	undistributed middle
cephalic index	guimpe	noi	Utopia
ceramics	hedonism	ohm	vantage-in
chamfer	hemiptera	parallax	way-bill
Chartism	homiletics	peneplain	Weismannism
chlorine	hydraulic press	Pestalozzi	wigwag
chromosome	impetigo	Polonius	X-ray
clearing-house	impressionism	pomology	Zionism

On the reverse side of this sheet define or explain the first five words that you have marked **D** and the first five words that you have marked **E**.

Results. — 1. Typical quantitative results, as obtained by

the writer from some hundred cases are embodied in Table I. Inspection of this table makes it evident that advance in school training (coupled with increased maturity) is accompanied by an increase in the number of technical terms that can be defined or explained, or that are at least 'roughly familiar.'

TABLE I.

DEPENDENCE OF RANGE OF INFORMATION ON AGE AND SCHOOL STATUS.

Academic Status.	Number.	*D*	*E*	*F*	*N*
Graduates	4	39.0	21.0	12.2	27.8
Seniors	5	20.6	17.2	25.2	37.0
Juniors	10	24.8	12.0	23.7	39.5
Sophomores	30	17.7	12.7	17.3	52.2
High-school	52	6.8	7.6	16.3	69.3

2. *Comparison of Sexes*, both in college and high-school students has indicated the superiority of men over women and of boys over girls. When both grades of students are combined the sex difference appears in the averages shown in Table II.

TABLE II.

DEPENDENCE OF RANGE OF INFORMATION ON SEX.

	Number.	*D*	*E*	*F*	*N*
Men	44	15.79	11.98	18.22	54.02
Women	57	12.21	9.42	17.19	61.17

3. The *definition-test* which is required serves to render the examinee more cautious in his marking: it also affords the examiner some index of the reliability of the marks obtained. Since, in the majority of the papers, both of high-school and of college students, there appeared one or more errors or inaccuracies in the ten definitions, it is evident that the results just figured must be discounted. For exact results, the examinee should be required, preferably orally, to define every word that he has marked *D*, and to explain or attempt to explain every word that he has marked *E* or *F*. In practice, especially when testing by the group method, such careful checking may prove too onerous: erroneous definitions may be neglected, or the quantitative data may be revised by discounting on the basis of the percentage of error revealed in the definitions. Or, again, the examiner may, after the test is concluded, define the 100

words, and let each member of the group revise his own paper by placing a second series of marks *after* each word to indicate the manner in which he should have marked it. A comparison of the sums of the *D*'s, *E*'s, *F*'s and *N*'s of the first and of the second series will then show approximately the extent and nature of the error due to ignorance or misunderstanding of the real meanings. In general, the sum for *D* and for *E* will be reduced, but there are in most groups a few persons who are overcautious in their first marking.

The nature of these errors in definition is sufficiently indicated by the following illustrations: the assumed source of confusion is indicated by the terms in parentheses after the definitions:

ageratum — an aggregation of objects: the aggragate (sic) amount.

annealed — pressed or rolled out thin: molded together.

Anthony Wayne — a historic character who was hung in the cause of freedom for the blacks: a man who fought in the Revolution on the English side.

Babcock test — a device to ascertain whether or not cattle have tuberculosis.

Base-hit — when the ball is hit and strikes a base or is caught there: a ball batted over a base: when the striker bats the ball into the pitcher's hands.

Bokhara — name of a place in Austria.

cantilever — a bar with a hook in one end by which lumbermen roll logs (cant-hook).

catalepsy — a form of disorder of the nervous system which causes fits or convulsions (epilepsy). (Similar statements given by 15 persons.)

chamfer — the tree from which camphor gum is obtained: this is the simplified spelling of it (!). (The confusion with camphor was found in 4 papers.)

clearing-house — a sale that takes place when a store wishes to dispose of its stock (clearing sale): a place where clearing papers are given to vessels to enable them to leave the harbor (customs house + clearing of vessels): picking up everything to move; taking everything out of the house: a place used by express companies to sell uncalled-for goods: a house where goods are made ready to be delivered.

cotangent — name of one of two tangents drawn to a circle from the same point without the circle: one lying alongside of (contingent): straight line drawn to touch a circle at one point (tangent).

dibble — to get just a smattering of some subject, as to dibble in medicine or politics (dabble): to do with divided interest (dawdle).

dryad — a priest of early English times (druid).

entrée — first course at a banquet, usually soup: something in the way of food, new and out of season: when the waiter brings in a new course it is called an entree: French for 'to-day': French for 'between' (*entre*).

Eocene — the term applied to one of the early ages of civilization.

Euclid — a book written by Vergil (Æneid): name given to certain trees (eucalyptus): an ancient Egyptian who studied geometry: name of an avenue in Cleveland, Ohio.

f–64 — means the temperature is 64 degrees above zero, Fahrenheit.
f. o. b. — cash on delivery (c. o. d.) : forward on board.
hydraulic press — a kind of air-pump, rather complicated, operated by suction and pressure : a machine for washing dirt from gold or from steep slopes (hydraulic mining) : the force with which water flows upon or against a thing, as a paddle wheel.
impressionism — when a man imitates the looks or actions of another : the art of exciting an impression.
infusoria — a chemical herb (infusion ?).
kilogram — the greatest quantity in the metric system : French measure of distance (kilometer) : French unit of liquid measure : the weight of a cube of water whose dimensions are a kilometer.
Les Misérables — a French tragedy written about the last part of the 17th century by Racine, one of the famous French writers : French work written by George Sand, author of Le Diable.
linotype — the product of a certain method of making prints from photographs.
Millet — a blind poet (Milton).
natural selection — in nature each animal selects its mate, a device for building up a stronger race.
ohm — German word for uncle (*Oheim*).
Polonius — a prominent character in Julius Cæsar.
pomology — the study of the palm of the hand, used by fortune tellers (palmistry).
tort — French word for ugly (*tors ?*).
triple expansion — the expanding of anything three times its normal size.
Utopia — a silk factory.
way-bill — a bill that is being considered
Zionism — same as Dowieism.

RESISTANCE OF KEYS AS A FACTOR IN REACTION TIMES.[1]

BY J. V. BREITWIESER, M.A.,
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The results tabulated in this paper are from records made in the psychological laboratory at Indiana University during the academic year of 1907–8.

A few records with varying resistances of the reaction key were taken in the summer of 1906. These showed an increment in the reaction time as the resistance of the reacting key was increased. With a view to further investigate this problem special keys were made and a program for more experimental data was arranged.

As finally formulated, the purpose of the experiment was, (1) To find what difference in the reaction time would be caused by increasing the resistance of the reacting key from 50 to 500, 1,000 and 1,500 grams; (2) to find the variation in the number of taps that could be made in five seconds with the same series of resistances; (3) to ascertain the changes in the reaction time for an isolated movement, namely, that of the last joint of the index finger with a series of varying resistances, beginning at 1,000 grams, and increasing 500 each time until it went beyond the lifting ability of the muscles involved.

As will be shown more fully below, the measurements for the records in tables 1, 2 and 3 were made with keys which required a movement like that of the ordinary telegraph key, while for those in No. 4 an ergograph was used.

Apparatus.

The apparatus used for measuring the reaction time was an improved type of pendulum chronoscope with accessories as designed by Professor Bergström. The original form of the

[1] From the Psychological Laboratory of Indiana University, J. A. Bergström, director till August 1, 1908.

chronoscope is described in the PSYCHOLOGICAL REVIEW, Vol. VII., No. 5, and that of the improved type with accessories was reported at the meeting of the American Psychological Association at Chicago in 1907.

The key, which was of the break circuit type, was so arranged that the tension of a spring could be brought to bear upon it so that various pressures could be required for the breaking of the circuit.

The signal for the reaction was given by a spring sounder with a scale showing the height of the hammer stroke, thus making it possible to make the strength of stroke perfectly uniform.

To count the number of the tapping movements a recorder like that described by W. L. Bryan in the *American Journal of Psychology*, November, 1892, was employed. The time for the tapping experiments was kept by a metronome which was checked with a stop watch.

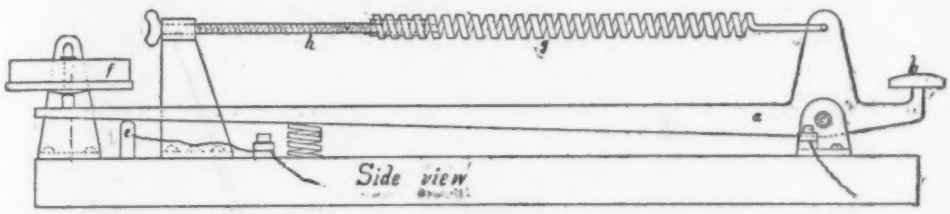

FIG. 1.

The key for recording the excess of pressure consisted of a long steel blade (*a*) (see Fig. 1) so mounted that the pressing button (*b*) was on the short arm of the lever, which was mounted on an axis at (*c*). Under the long arm of the lever was fastened a short spring which allowed only a small movement for a considerable increase in pressure. This spring did not exert any pressure when the lever was at rest, and served as a resistance for the excess pressure which was measured, as will be described below, by the height of stroke on a kymograph drum. A brass post (*e*) stood under the long end of the lever where the current was made or broken with the platinum contacts. It was the breaking of this current which stopped the chronoscope in the reaction experiments. The end of the lever was in connection

with a tambour (*f*), a tube from which ran to the recording tambour writing on a kymograph drum which recorded the movement of the lever after the connection at (*e*) was broken. The varying resistances were introduced by the spring (*g*), the tension of which was varied by the screw (*h*).

The up stroke of the recording tambour therefore drew a line on the revolving drum which was proportional to the excess pressure exerted on the key. Various measured pressures were then put on the button (*b*) of the key and the height of the stroke of the recording tambour measured on a scale. With this scale the tambour strokes could be measured and their value recorded in terms of grams of pressure on the key.

The records given in the tables were taken throughout a period of 46 weeks. Usually a full set was taken at a sitting with rests between trials to avoid fatigue which seemed to have much influence especially with the heavier resistances. All records are recorded in thousandths of a second. A few records were discarded where it was known with certainty that the subject had been disturbed by outside influences. Subjects were kept as free as possible from distracting disturbances and were asked in every instance to give as nearly as possible a uniform concentration of effort on work at hand. An attempt was made to have all records made with the same kind of movement so as to have as nearly as possible the same muscles to deal with.

Tables of the results show in each instance the amount of resistance of the key and the corresponding record, also the mean variation. A 'ready' signal was given for every reaction and then the sounder was snapped and the time interval between snap of key and subject's pressing of key recorded. All reaction records are to auditory stimuli and of the motor type.

Program for Daily Experiment.

In the first series of experiments the resistance of the reaction key was set at 50, 500, 1,000, and 1,500 grams. A record of ten reactions was taken with each of the respective resistances and then the order of reacting so that ten records were taken again for each resistance, but beginning at 1,500 grams and

going back to the 50 grams. This programme was followed by all the subjects. They were never allowed to quit without completing this program; thus there were never less than 80 reaction records taken at a sitting. The purpose of this program was to equalize the effect of practice and fatigue on the reactions for the respective resistances.

In the second series of experiments, an ergograph [1] was employed as a reacting key in connection with the pendulum chronoscope; and so arranged that whenever a certain amount was lifted on the ergograph it recorded the reaction time on the chronoscope in much the same manner as the keys used. This reacting movement had the advantage of isolation and uniformity. In this experiment the index fingers were used and only the end joint allowed to move, the finger being so clamped as to isolate this movement from the rest of the hand.

When the ergograph and the chronoscope were used together the following method was employed. Ten reaction records were taken for every resistance, beginning with 1,000 grams as the lightest and increasing the amount by 500 grams each time. This increase was continued up to a point where the subject was unable to lift the weight, then the reverse order was taken with ten readings for every 500-gram variation in weight running from heavy to light. The ergograph resistance is counted as if applied 31.8 mm. from the center of rotation of the joint.

The subjects who served in the experiments were chosen from the regular students working in the psychological laboratory. For the beginning experiments they were Mr. Smith and Mr. Durgee. The remaining two thirds of the school year Messrs. Miller and Harris acted as subjects. They will be referred to by their respective initials. The writer also acted as a subject in all experiments except where the ergograph was used as a reacting key; he will be designated by the letter B.

All subjects had done over twelve weeks of experimental work in psychology. H. and M. were especially strong men and had shown themselves to be very steady in experimental work. H. was about 27 years old, M. 25. None of the subjects had any preconceived notions as to what the results of the

[1] J. A. Bergström, 'A New Type of Ergograph with a Discussion of Ergograph Experimentation,' *Am. Jour. of Psych.*, Vol. 14, 1903.

experiments would be and their effort in all the reactions was to make them as quickly as possible.

From the experiments thus performed we have the following results:

The averages for 125 reactions each for 50, 500, 1,000, and 1,500 grams resistance were as follows, the reaction records being made by S., D. and B. on the first type of key used, which did not record the excess pressure. We also have the averages of thirty-five records of the number of taps made in five seconds on the same key. The resistance for the tapping records being the same series as in the reaction records. The records of this table are regarded as preliminary, and are therefore given merely as simple averages.

TABLE I.

Resistance of Key.	50 Grams.	500 Grams.	1,000 Grams.	1,500 Grams.
Av. reaction time for all records of S., D. and B.	112.8	127.5	141.8	149.7
Av. No. of taps in 5 sec. S.	57.8	56.5	54.8	52.3
Av. No. taps in 5 sec. B.	52.6	48.8	44.2	40.8

In Table II., in which the results are given more in detail, will be found averages for 180 reaction records for each resistance made by H., M. and B. on the second key, described above, which recorded the excess of pressure in the reaction. A few tapping records are also reported. The same resistances were used as in Table I.

TABLE II.

Resistance of Key.	50 Grams.		500 Grams.		1,000 Grams.		1,500 Grams.	
		M. V.		M. V.		M. V.		M. V
Average reaction time for H.	71.3	12.6	92.2	12.6	102.3	12.	108.6	13.
" " " " M.	98.1	11.8	116.5	8.4	130.5	11.5	139.3	10.2
" " " " B.	75.	12.	89.6	10.4	102.9	10.4	119.8	9.2
" " " all	81.7		99.3		111.9		123.2	
Mean variation for all.	14.23		10.49		11.22		10.86	
Average No. of taps in 5 seconds for all.	49.6		49.2		44.8		41.8	

In Table III. will be found averages of the measurements of the excess pressure used. Excess pressure is that above what was necessary to break the circuit which stopped the

chronoscope index. The results which are given in grams are as follows:

TABLE III.

Resistance of Key.	50 Grams.	500 Grams.	1,000 Grams.	1,500 Grams.
Average excess for H.	711.2	864.1	1,081.2	1,171.6
" " " M.	854.0	970.5	802.0	891.6
" " " B.	814.1	1,327.9	1,202.9	935.3
" of all readings	793.2	1,051.1	1,028.7	998.8

To measure the effect of practice on the excess pressure used, the average excess for each successive day was found, the subject going through the program as stated above. The results are given in Table IV.

TABLE IV.

Successive days.	B.	M.	H.
1	1187.5	1493.0	1869.37
2	880.0	1321.25	1333.67
3	1120.0	655.62	921.25
4	911.2	605.0	661.25
5	758.7	480.62	827.5
6	653.7	694.37	
7	884.3		

While there are two exceptions in B's averages and one each in M's and H's there appears to be a decrease in the amount of excess on successive days. Table V. gives the averages of reactions with the ergograph, used as the reacting key, in which the last joint of the index finger was used to produce the movement. This table shows the average of twenty

TABLE V.

Resistance in Grams, 31.8 mm. from Center of Rotation of Joint.	Reaction Time. M.	Reaction Time. H.
1,000	85.0	88.3
1,500	85.5	109.6
2,000	94.1	117.3
2,500	101.8	121.6
3,000	103.3	136.5
3,500	112.3	147.3
4,000	112.8	157.6
4,500	124.9	164.2
5,000	154.0	183.3
5,500		209.3
6,000		216.8

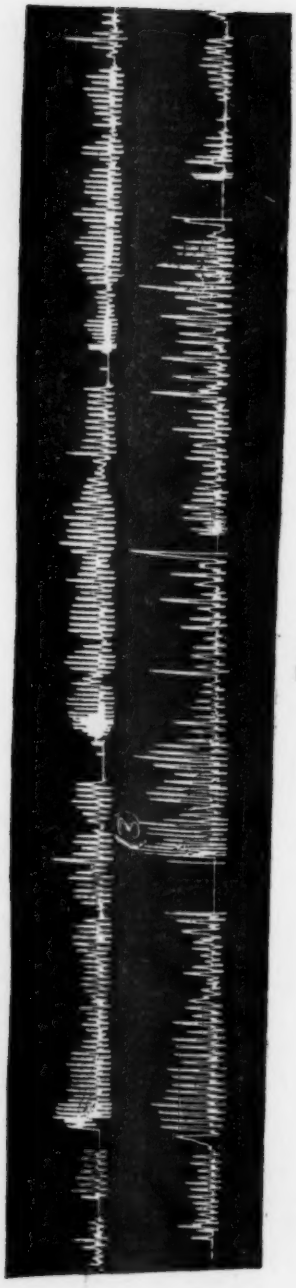

FIG. 2.

records for each weight. This series was the last taken, the subjects having thus had the practice of all the previous experiments.

Near the limit of the muscle ability to move the weight, the reaction time is evidently nearly double what it is at the beginning.

In Fig. 2 is given a part of the kymograph record of the excess pressure used in tapping. It shows that the excess, or surplus force, was expended in rhythmic or pulse-like beats for the curve runs in a wave form. One curve for five seconds began at an excess of five hundred grams which increased in about five taps to an excess of from 800 to 1,200 grams, then lowered to 50 grams and then rose again to the same excess. The number of taps between the greatest excesses varied from 10 to 20. The increase or decrease of a series of excess averages is usually regular, yet isolated high or low records also occur.

From the above tables of results we may draw the following conclusions:

1. Reaction time is lengthened or shortened, respectively, when the resistance of the reacting key is increased or decreased within the limits employed. The resistance of the reaction key should therefore be made definite, and should be stated in reaction experiments.

2. The rate of tapping is greates

with the minimal resistance employed, and decreases as the resistance is increased.

3. The excess force used in a reaction movement does not seem to vary in a marked or definite way with the resistance, in other words, it is largely independent of it.

4. The graphic records for the excess show a tendency towards rhythm, especially in the tapping records.

5. The excess diminishes (more or less regularly) with practice. (Table IV.)

A peculiar fact (perhaps worth noting) is that with the ordinary reaction key M.'s records were longer, while with the ergograph his records were shorter than H.'s. The evidence in detail will be found in Tables II. and V.

Some work on this and closely related problems has already been done. In 1892, M. Ch. Féré[1] arrived at the following conclusions:

For one and the same subject the reaction time is longer according as the weight to be lifted is heavier — provided that the weight is not known beforehand. When, however, the weight to be lifted is known to the subject beforehand the length of reaction time does not vary regularly with the weight, but with the capability of the subject to adapt his attention.

It was found however in our experiment, that even though the subject learned the resistances, he still had an increment in his reaction time that increased as the resistance was increased.

Helmholtz found that the total muscular force was not developed instantaneously. Haycraft[2] of the University of Wales, working upon this problem found that if a muscle be lightly loaded, the muscular force sufficient to raise the weight will be developed say in $\frac{1}{100}$ of a second; if it be loaded with a heavier weight, the greater muscular force requisite to raise it in this case will not be developed say for three or four hundredths of a second.

The amount of pressure was measured by Delabarre[3] in his experiment on the force and rapidity of reaction movement.

[1] *Comptes Rendus de la Société de Biologie*, 9th Series, Vol. IV., 1892, pp. 432–435.

[2] *Journal of Physiol.*, Vol. 23.

[3] PSYCHOL. REV., Vol. IV.

He made a study of temperament by taking the reaction time itself, the degree of pressure used by the subject, and the rapidity with which he contracted his reacting muscles. The degree of pressure in this case was measured by the height of a mercury column forced up by the reacting movement. In this experiment as well as the one reported by Féré, we have the force of inertia to overcome at the beginning of the reaction movement while in the experiment reported in this paper all resistances were made by varying tensions of springs, thus reducing the effect of inertia.

If we attempt an explanation of the effects observed one of the possible explanations is that the tip of the finger is capable of quite a good deal of compression and that perhaps some little time was consumed in bringing about this compression before the key was actually moved, which would make the heavy reactions longer than the light. To a slight extent this must be true, but not to a very great extent, especially in the ergograph reactions which followed the same law of increment, for here the finger was placed snugly in a thimble where the compression on all sides was great enough to move the resistances with very little compression.

It has been shown in physiological experiments that muscles have a certain amount of elasticity. Lombard in speaking of the effect of different weights on the gastrocnemius muscle of a frog says: "There can be no movement of the lever until the inertia of the weight has been overcome and the first effect of the contraction is to stretch the muscles, a part of the energy of contraction being changed to elastic force, which on the recoil assists in raising the weight. Thus the myogram may fail to reveal the instant that the contraction process starts.

"Inasmuch as tension increases the activity of muscle protoplasm it is probable that the presence of the weight really hastens the liberation of energy at the same time that it delays the recording of the contraction." This seems to be a very probable explanation for the increase of the reaction time with the increase of the resistance, and may be regarded as one of the chief factors in producing the results recorded above.

A further explanation may be that the nervous impulse itself

is a thing of volume and requires time in formation and conduction, and the greater the strength of impulse required the longer the time required to get the requisite amount of stimulation to the nerve ending. The subjects felt the constantly increasing sense of effort the greater the resistance. This may however have been the feeling arising at least in part from the external movements resulting from the effects of the effort put forth. This also is a possible partial explanation of the results.

ANNOUNCEMENT.

THE seventh International Congress for Psychology will be held in 1913, in the United States, the city to be determined later by the committee in charge. The following officers have been appointed: Honorary President, William James; President, J. Mark Baldwin; Vice-Presidents, E. B. Titchener, J. McK. Cattell; General Secretary, John B. Watson. A report of the sixth Congress, held in Geneva last month, will appear in an early number of the BULLETIN.

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